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AID Report 62-3a

NATIONAL WEATHER SERVICE, USSR

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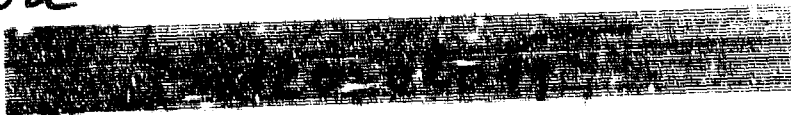
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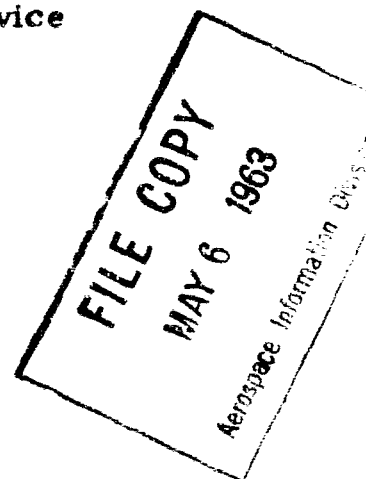
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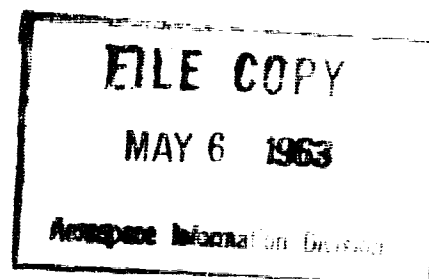
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INTRODUCTION

The Soviet Hydrometeorological Service has experienced two major reorganizations since its establishment in 1921. Hence, the history of the Service and its organizational structure can be divided conveniently into three periods marked by the reorganization dates of 1929 and 1936.

From 1921 to 1929, under the direction of the Main Geophysical Observatory, the various meteorological and hydrological networks expanded so rapidly that the Observatory with its limited staff and resources could no longer properly direct, coordinate, and plan the present and future operations of the Service.

Under the direction of the Unified Hydrometeorological Service (Yedinaya gidrometeorologicheskaya sluzhba), established in 1929, the various networks were coordinated and consolidated and were placed under the immediate supervision of subordinate administrations of the Hydrometeorological Service. The Main Geophysical Observatory resumed its scientific, methodological, and research work, and the aerological program developed with an increasing number of radiosondes and pilot-balloon observation points.

The last major reorganization in November 1936 was necessitated by the continued expansion of the observation networks and the increasing degree of specialization in meteorology, aerology, hydrology, oceanography, marine meteorology, and agrometeorology. Most of the central and regional scientific research institutes now in existence were established after 1936. In the postwar period, the work has expanded greatly, especially in the Asiatic USSR and other previously poorly covered areas.

The Fortieth Anniversary of the Hydrometeorological Service in the USSR was marked by a National Meteorological Conference in Leningrad, 21 to 29 July 1961, in which more than 1400 persons participated. The full texts of the 450 reports presented at the conference are scheduled for publication in a collected set. [As of 1 May 1962, none of the set was available at the Library of Congress.] In the advance notices of the collection there are general remarks on reports by the following specialists: 1) I.M. Dolgin, D.L. Laykhtman, N.P. Rusin, and A.D. Treshnikov reported on investigations in the Arctic and Antarctic. 2) E.K. Fedorov's report dealt with progress made in the modification of cloud formation, fog, and precipitation. 3) Reports by B.A. Mirtov and P.G. Khvostikov centered on investigations of properties of the atmosphere at great heights through the use of rockets and artificial earth satellites. 4) V.A. Bugayev made a survey of the present status and prospects of developing the synoptic method of weather forecasting. He noted that progress in numerical methods of forecasting meteorological fields has de-emphasized investigations of such significant processes as the genesis and evolution of frontal discontinuities and cyclogenesis.

5) M.I. Budyko reported on work of climatological interpretation of data on the heat balance of the underlying surface and of the atmosphere. Of considerable interest is the section of his report dealing with physicogeographical zoning. By using the heat-balance method, Budyko showed that the decrease in temperature poleward from the equator is not only the result of smaller angles of incidence of the sun's rays, but also of the ice cover in the Arctic and Antarctic.

6) A.M. Obukhov reported on results and prospects of investigations of atmospheric turbulence. Recent major accomplishments in this field are attributed to the development of highly sensitive and improved apparatus for "pulsation" (micro-oscillation) measurements and the formulation of a theory encompassing the laws governing atmospheric turbulence close to the earth's surface.

7) Kh.P. Pogosyan discussed questions of the general circulation of the atmosphere. Pogosyan exhibited the maps which he had compiled showing the mean distribution of the heights of a number of isobaric surfaces for the stratosphere in both hemispheres.

8) F.F. Davitaya's report dealt with a study of agroclimatic resources of the USSR. A survey of agroclimatic investigations of the past forty years emphasized that despite progressive advances in agricultural techniques, the role of meteorology is still important.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph a

SOURCES: See list of references below.

**"THE RELATIONSHIP OF THE AGENCY PROVIDING NATIONAL WEATHER
SERVICE TO THE AGENCIES PROVIDING WEATHER SERVICE TO
THE SOVIET ARMED FORCES"**

Since the first governmental decree ordering the establishment of a national weather service in the USSR in 1921 and subsequent decrees ordering its first and second reorganizations in 1929 and 1936, the central administrative organ of the National Weather Service, now the Main Administration of the Hydrometeorological Service (GUGMS), has had the responsibility of serving both the national economy and the national defense in the fields of meteorology, climatology, aerology, agrometeorology, hydrology, and marine hydrometeorology [1]. According to A. A. Zolotukhin [2], the present Chief of GUGMS, the decree of 14 November 1936 "defined the great national importance of the Hydrometeorological Service, its responsibility for the proper study of hydrometeorological conditions in the USSR, and its service to the national economy and the national defense."

Relations between GUGMS and military agencies providing weather services to the Soviet Armed Forces have varied greatly from wartime to peacetime and from one military agency to another. In World War II, GUGMS and its organs functioned as a military organization with subordinate administrations serving the various military fronts, military districts, and navy fleets [3].

The demilitarization of the internal organizational structure of GUGMS, which took place in the early postwar period (1946-1948), with the rapid restoration of stations, facilities, and communications destroyed during the war, must not be interpreted as a severance of the military weather services from the now restored national civilian service. With demilitarization, each military agency responsible for providing weather service or maintaining weather stations and posts to serve its own particular requirements resumed its identity within the Armed Forces [4; 5]. It must be emphasized that there is no single, self-sufficient large-scale or general weather service in any military agency. For this reason, all military agencies must depend on GUGMS and its organs for dense-network observational data, forecasts, storm warnings, and advisories. These services are readily obtainable on a routine basis from regularly scheduled radio broadcasts or teletype sequences or on a special basis through other means of communication, such as telegraph and telephone.

In peacetime, GUGMS and its organs serve primarily the national economy, although any operative organ of the Service (hydrometeorological and weather bureaus, observatories, aeronautical weather stations, and certain first-order stations) will upon request from a military agency provide special or detailed observations, forecasts, and hazardous-weather warnings, etc., with sufficient advance notice to arrange for the collection and transmission of timely reports, forecasts, and other services required for planning and executing (or postponing, modifying, or canceling) a particular military mission on a specific date [6].

The close connection between the civil and military weather services during the pre-World War II period is shown in the 1936 organizational chart of the Meteorological Service (Fig. 1) [7]. Although the latest (1960) organizational chart of the Service (Fig. 2, explained in Paragraph c) indicates only one direct link between the civil and military weather services -- through the Main Aviation Weather Center in Moscow [indicated by the letter N on the 1960 chart] -- recent literature [e.g., 10] attests to the continued dependence of the military agencies on GUGMS for general, special, and supplemental services. However, the relationships between GUGMS and the military agencies vary from service to service.

The Main Aviation Weather Center maintains liaison with the Main Aviation Weather Station (also in Moscow), the central organ of the Military Air Force Weather Service [11]. This is apparently a logical interrelationship in view of the highly organized weather service provided by the Air Force and the current emphasis on modernization of aeronautical weather services in both civilian and military agencies [12].

Modernization is imperative if the requirements of high-speed and high-altitude jet aircraft are to be served with efficiency. The program must include the latest in observational techniques, instruments, automatic-recording broadcasting and telemetering installations such as radar [13], automatic radio weather stations in remote and inaccessible areas [14], and automatic or telemetering recorders of visibility and cloud-base heights [15].

The modernization of the civil weather service is being accomplished largely through the collaboration of GUGMS and the Main Administration of the Civil Air Fleet (GUGF) [16]. The Civil Air Fleet, which according to Director Ye. Loginov [17] can readily be adapted to military requirements on short notice, must keep in mind the military specifications of its aircraft and facilities in any individual or joint efforts to modernize weather service. In recent years, scientific research institutes of both GUGMS and GUGF have been collaborating in studies of aircraft icing, turbulence, jet streams, and other problems associated with flight in the upper troposphere and lower stratosphere and of the modification of local or regional weather factors affecting the safety and dependability

of flights [18]. GUGMS and GUGF are also collaborating in modernizing communications and traffic control systems through 1) the installation of radar observation posts at points along air routes [19], 2) the placement of synoptic meteorologists and facsimile map facilities at traffic control centers, and 3) the installation of map-copying machines at ^{avia 1811} aeronautical weather stations.

Of the other military agencies maintaining special weather services, the Artillery Command with its own Artillery Meteorological Service depends on GUGMS for forecasts, advisories, and other detailed information which may have an effect on movement on and off roads and on artillery operations at specified times and places. The Artillery Meteorological Service maintains three different programs of special meteorological observations for its ground artillery, antiaircraft artillery, and acoustical ~~and~~ ^{and} reconnaissance operations [20]. The organization and work of these programs will be described somewhat more fully below.

The Chemical Warfare Service, which also provides its own special services, similarly depends on GUGMS for general weather service [21; 22]. A sketch of this organization and its work will be given below.

Other military agencies requiring hydrometeorological services are transportation units and Rear and Supply (Quartermaster) units. No information is available on the weather information channels these services maintain or on any attempts at modernization of observation work under poor visibility conditions with new techniques such as radar.

GUGMS, its scientific research institutes, and major operative field organs (observatories, bureaus, and certain major stations) publish a great deal of valuable data and specific information from their investigations and studies. These include monographs and articles on general and regional themes in synoptic meteorology, climatology, micrometeorology, marine meteorology, agrometeorology, and related fields. In addition, the republic and territorial administrations of the Service publish a large amount of primary data in the form of 10-day, monthly, and annual summaries for each of their administrative areas. These data are readily available for planning military operations within specified areas at various times of the year. The detailed data available on snow-cover distribution in the USSR (by depth and dates of occurrence) published by the State Hydrological Institute (a central scientific research institute of GUGMS) is a striking example of the special service the National Weather Service provides both to the national economy and the national defense.

It is evident then that GUGMS has been organized internally in such a manner that subordinate administrative and field organs are given sufficient autonomy to provide flexibility of service in the form of supplemental detailed reports, forecasts, and other

services between standard synoptic hours as may be required for both civilian and defense needs without unnecessary and time-consuming channeling of such services through higher organs. At the same time, GUGMS, through centralized direction and supervision of its higher central and field organs, maintains absolute control over the entire system. Furthermore, the Service makes available its entire resources of climatological data and the results of its investigations and studies in meteorology and in the related fields indicated above.

It should be mentioned that many Service personnel who were military meteorologists during World War II serve actively in the All-Union Voluntary Society for the Promotion of the Army, Air Force, and Navy (DOSAAF). This group maintains strong educational, training, and propaganda programs and publishes elementary and intermediate textbooks on military themes. [There are only a few such meteorological textbooks available in U.S. Libraries, e.g., sources 23-25.]

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SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph b

SOURCES: See list of references below.

STRUCTURE OF THE AGENCIES PROVIDING WEATHER SERVICE TO THE SOVIET ARMED FORCES

As noted in Paragraph a, the military weather service agencies depend on the national civil weather service [GUGMS] for both routine and supplemental weather services in peacetime. This is discussed more fully in Paragraph c, below.

Available information indicates that there are three military organizations -- the Air Force, the Artillery Command, and the Chemical Warfare Service -- which maintain weather posts and stations and conduct their own weather observation programs [4, p. 8]. Of these, only the Air Force issues its own weather forecasts and warnings, and even these rely heavily on the services of GUGMS and its field units.

Although little detailed information is available, a rough notion of the organizational structure of the three military weather agencies can be formed from a study of the routine missions of their subordinate units and the responsibilities of their higher echelons and commanders.

I. THE AIR FORCE WEATHER SERVICE

History of the Air Force Weather Service

Prerevolutionary aviation weather service began in 1910, with the establishment of weather stations to service the first flight schools in Russia. The increased importance of aviation in World War I led to the creation of the Main Military Meteorological Administration and the organization of army staff sections for weather. Military weather stations were established in the aviation branch to provide direct weather service for military aviation.

From 1916 to 1921, the responsibility for aviation weather service devolved on aeronavigation stations making atmospheric observations and compiling aviation forecasts. After May 1921, problems in relaying data and reports were solved by wiring meteorological flight information to the Commissariat of the Postal and Telegraph Services.

The first nationwide meteorological service in the RSFSR was created by the decree of 21 June 1921. The subsequent development

of the Air Force Weather Service closely parallels that of the civil weather service [GUGMS] described in Paragraph c. In 1923, the Central Aeronavigation Station was established at the Moscow Experimental Airport. This center provided meteorological flight information and calibrated aeronavigation instruments until the Air Force's Main Aviation Weather Station was established at Moscow in 1926. The latter is still the central establishment of the Air Force Weather Service. [11, p. 8]

The 1930's saw the development and expansion of the aerological network of radiosonde and pilot-balloon stations and the introduction of the Molchanov radiosonde. Progress in aviation weather service was so rapid that in 1940 the national civil weather service [GUGMS] established a special scientific research institute, the Central Aerological Observatory in Moscow, to investigate problems of weather forecasting in general and aviation in particular. The work of this institute, as well as the further development of aviation weather services since World War II, is discussed in Paragraph c.

The Weather Service at the Headquarters Level

The Air Force Weather Service can be identified indirectly on the latest available organization chart of the Air Force Main Staff (see Fig. 3). The meteorological section is one of those which, by virtue of their duties, are more autonomous in relation to the General Staff, although of course some liaison is necessary. [26, p. 177]

Weather Service for Flight Operations

The functions of the Air Force Weather Service at military airports parallel those of the civil weather service at Civil Air Fleet airports. Specifically, it provides 1) information on current weather conditions, 2) forecasts and hazardous weather warnings, and 3) climatological data and information. The Air Force Weather Service utilizes not only the data provided by its own personnel, but also information gathered by the entire national network of GUGMS stations.

The regular use of data from GUGMS sources assures continued close contact between the two organizations. Similarly, meteorological observations made by every aviation agency in the USSR are coordinated, systematized, and disseminated by GUGMS to all other aviation agencies. The operations of Air Force Weather Service units are systematized in instruction manuals issued by the Air Force Weather Service.

Headquarters, Air Forces (GU-VVS)

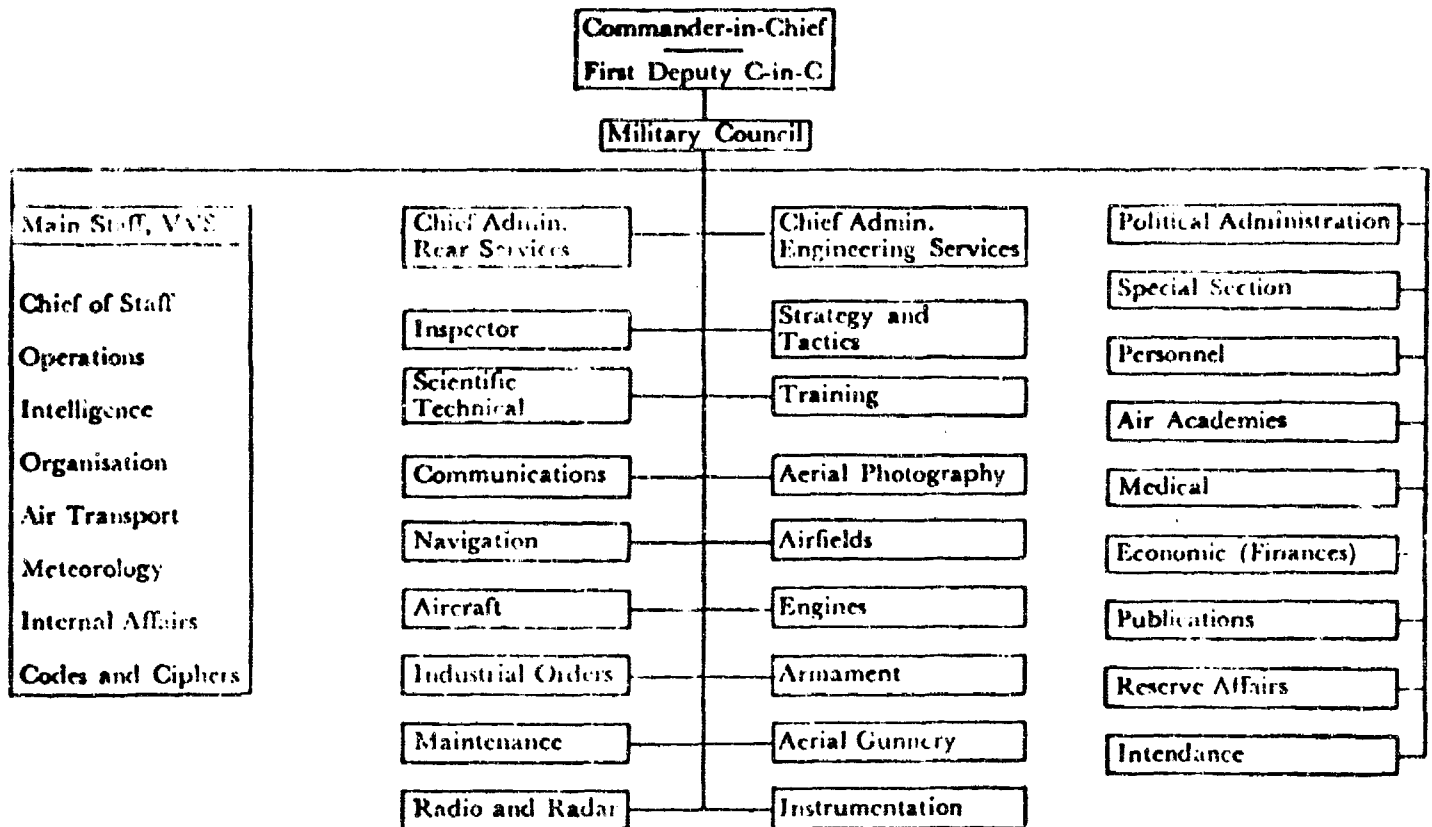


Fig. 3. Organization chart of Headquarters, Air Force USSR [26, p. 177]

Preflight weather briefings. Air Force flight plans require more comprehensive preflight study than Civil Air Fleet flight plans, since the officer issuing the flight clearance must be sure that personnel and aircraft can cope with any exigencies due to weather changes not predicted in routine or special forecasts. Operational flight plan modifications are made to minimize adverse weather effects. Examples might be changing from visual to instrument flying or changes made to exploit changed weather conditions.

To provide sufficiently detailed weather data for preflight analysis, Air Force Weather Service meteorologists are required to a) compile a sufficient number of synoptic and upper-level maps; b) obtain weather data for the proposed route in case it is not available from routine transmissions; c) obtain supplemental aerological data (winds and temperatures aloft, heights of cloud bases and tops, thickness of clouds, etc.); d) analyze all

current weather data, compile forecasts for the plane commander, and analyze preliminary data just before the flight; e) brief the plane commander and crew before take-off, keep the *Pilots' Weather Bulletin* updated, and interrogate flying personnel concerning weather conditions actually encountered; and f) maintain continuous observations, check the special forecasts, and issue warnings on all weather changes not covered by forecasts and hazardous condition warnings.

Aerial weather reconnaissance. Another activity of the Air Force Weather Service is aerial weather reconnaissance. This may be conducted on command or as desired by the meteorologist and serves the purposes of 1) collecting additional data from areas for which existing data are inadequate; 2) collecting additional data on front conditions or synoptic conditions for which surface-station data are not sufficiently detailed; and 3) obtaining data for altitudes where the collection of data by other means is difficult or impossible.

Reconnaissance is conducted below cloud level in order to appraise meteorological conditions more accurately; above cloud level, to obtain data on the altitude of cloud tops and appraise flight conditions; and within clouds, to determine flight conditions, icing conditions, cloud mass, and degree of stratification. Aerial reconnaissance utilizes either specially equipped "flying weather labs" or ordinary combat and transport aircraft. Meteorologists occasionally accompany the reconnaissance plane to collect instrumental data in addition to the visual observations made by the air crew.

The reconnaissance is regarded as complete only if flight conditions can be ascertained at the three levels mentioned above. Therefore the reconnaissances are usually made by a single aircraft maneuvering vertically or by several aircraft at different altitudes.

Weather service to in-flight aircraft. Weather information is voice transmitted by radio between ground and aircraft, just as in the Civil Air Fleet. The navigator may request special observations and other information at any time from the nearest weather station; in his turn he keeps the weather stations posted on any significant weather changes which he observes (see Fig. 4.). [6, p. 54]

Main Weather Center

The Main Aviation Weather Center in Moscow (at Vnukovo Airport) is the central coordinating agency linking GUGMS and the aviation weather services of other government departments. A brief discussion of its work and its relationship to GUGMS is given in Paragraph c. It is represented on the 1960 GUGMS organization chart by the letter "N". (See Fig. 2.).

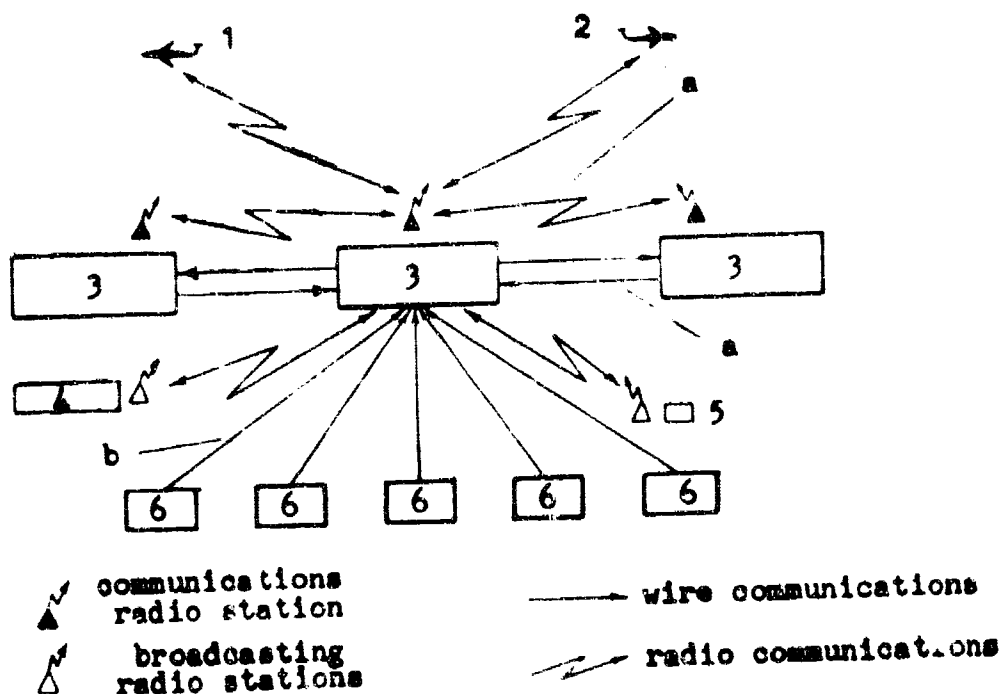


Fig. 4. Diagram of weather data collection and transmission at weather stations [6, p. 56]

1 - weather reconnaissance aircraft; 2 - aircraft in flight; 3, 3, 3 - aviation weather stations; 4 - central forecasting institute; 5 - weather bureau; 6, 6, 6, 6, 6 - meteorological stations. a - routine exchange of requests, replies, and storm warnings; b - storm warnings and replies to requests.

II. THE ARTILLERY WEATHER SERVICE

History of the Artillery Weather Service

Established in 1926, the Artillery Weather Service has passed through three developmental stages. During the first period, from 1926 to 1940, wind soundings were taken by single-point pilot-balloon observations. The basic unit of the Artillery Weather Service during this period was the artillery weather post. [27, p. 172]

The second period, from 1941 to 1945, saw the introduction of the double-theodolite (or base-line) method of pilot-balloon observation and the comb-radiosonde method of making temperature soundings. The basic unit of the Service during this period was the artillery weather platoon.

The postwar period, since 1946, has seen several innovations, including the use of radar in making wind soundings and some research on new or improved methods for complex atmospheric soundings. The present basic unit of the Artillery Weather Service is the recently developed mobile artillery weather station, around which the artillery weather batteries, consisting of artillery weather platoons, are organized. The development of the mobile station actually marks the beginning of a new period for the Service, although the deployed type of weather posts are still in use alongside the newer units.

The Mobile Artillery Weather Station

The mobile artillery weather station, because of its advantages over the former fixed stations, makes possible the solution of a number of complex problems of artillery weather service under field conditions. The basic instruments and equipment of the station are housed and transported in a tractor-trailer. The radiosonde release point is located on the truck, and complex sounding results are processed there. The trailer contains a hydrogen gas generator for field use, a gasoline-powered generator assembly to power the radiosonde, and storage space for expendable supplies. New and improved instruments and equipment have been placed in the mobile artillery weather station, including a pressure chamber for pressure-calibrating the radiosonde, a field radiosonde lab for calibrating and adjusting the radiosonde prior to release, and theodolites and other instruments necessary for double-theodolite pilot-balloon wind observations. Even with the mobile station, however, wind soundings cannot be made when clouds and fog cause poor visibility.

Special Observation Programs

The Artillery Weather Service maintains three programs of weather observations as part of its reconnaissance.

Field Artillery observations include a) ballistic wind, for trajectory elevations prescribed by the Artillery Staff; b) ballistic temperature deviations for prescribed trajectory elevations; and c) near-surface atmospheric pressure and air temperature deviations from their standard table values (taken at the platoon deployment station).

Antiaircraft Artillery observations include a) ballistic wind by standard increment up to shell burst altitude and at other altitudes as prescribed; b) ballistic air temperature and air density differentials for these altitudes; and c) near-surface atmospheric pressure, air temperature, and air density deviations from the standard table values.

Sound Ranging observations include a) surface air temperature; b) surface wind velocity and direction; and c) air temperature, wind direction, and wind velocity distribution at the standard altitudes of 50, 150, 300, 500, 700, 900, and 1100 meters above the station site.

Missions of the Artillery Weather Service Units

The artillery weather platoon conducts surface observations of air temperature, humidity, and pressure; wind velocity and direction; cloud cover; and other atmospheric factors. The platoon also performs wind and temperature soundings and is responsible for processing the data obtained and transmitting the sounding results to Army headquarters in coded form. The coded weather bulletins produced by the artillery weather platoon are called meteo-firing, meteo-antiaircraft, and meteo-soundings, respectively.

Upon receipt of the order to deploy, the commander of the weather platoon will a) secure intelligence on the enemy; b) locate the deployment area; c) set up schedules for making atmospheric soundings and transmitting weather bulletins, decide on the elevations to be covered by individual bulletins (for rocket field artillery and antiaircraft), and determine what technical means will be required for upper wind soundings; d) direct platoon movements and maintain contact with artillery headquarters; e) keep the DivArty commander informed, during deployment, of the location of the elements under his control (e.g., the mobile artillery weather station, surface weather observation points, first and second theodolite points,

wind sounding radar installations, and communications radio center); and f) insure that the platoon stays within 30 km of the combat artillery units in flat country, and at the same elevation and much closer in mountainous country.

The mission of the weather posts is specialized and limited. Rocket field artillery weather posts determine the wind direction and velocity at a height of 3 m above the ground, while sound ranging weather posts observe air temperature and wind direction at a height of 2 m above the ground.

The Artillery Weather Service and GUGMS

GUGMS provides the Artillery Weather Service with detailed weather and hydrologic data for specific areas as requested and the routine and special forecasts necessary for planning artillery operations.

The Artillery Weather Service and Other Military Agencies

By broadcasting the three types of weather bulletins described above, the Artillery Weather Service makes its observation results available to all military agencies.

III. CHEMICAL WARFARE WEATHER SERVICE

[Information in this section was taken from a 1941 source.]

Weather Factors in Planning Chemical Warfare Operations

Chemical warfare requires meteorological observations for factors influencing the effectiveness of the offensive use of chemical agents and defensive countermeasures against chemical attack. To properly evaluate the effect of weather on offensive or defensive chemical warfare operations, one must know the wind direction and velocity, the air temperature, and the air stability aloft (presence or absence of inversions). Precipitation, cloud cover, pressure, and humidity effects must also be taken into consideration. Only certain combinations of weather factors constitute a favorable weather situation for offensive or defensive chemical warfare operations. [22, p. 235]

Organization of Chemical Warfare Weather Stations

The chemical warfare regiment's weather station deploys on the order of the Chemical Warfare Officer, usually in the vicinity of the regimental command post. A suitable site for making weather observations (i.e., without local obstructions and at least 100 m from the nearest wooded area) is selected by the OIC of the weather station. A site which lends itself to camouflage measures is chosen if possible. The relatively simple instruments and equipment include a wind-sock or tell-tale, a Feuss anemometer, a compass, a sling psychrometer, watches, portable posts, eight pegs marked with the points of the compass, a flashlight, a journal for the observations, an instrument case, and a manual of weather station procedures. An aneroid barometer and a cloud atlas are optional equipment. After the station site has been selected, the OIC of the station (usually a junior officer or the enlisted man best trained in chemical warfare) issues instructions to include the following: location of the enemy, the weather elements to be observed, the duty roster and schedule, and the transmission schedule and distribution list for weather reports. Then the station is put into operation. Usually four to six persons are assigned to a 24-hour station. [22]

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph c

SOURCES: See list of references below.

**"ORGANIZATION OF THE AGENCY PROVIDING WEATHER
SUPPORT TO THE SOVIET ARMY"**

As was noted in Paragraph a, the central administrative organ of the Soviet government responsible for providing meteorological and hydrological services (the Hydrometeorological Service) for both the national economy and the national defense is the Main Administration of the Hydrometeorological Service USSR (GUGMS). On the accompanying 1960 organization chart of the Hydrometeorological Service (Fig. 2), GUGMS is designated A. By the governmental decree ordering the reorganization of the Service in November 1936, GUGMS was given the responsibility of providing the national economy and the national defense with hydrometeorological information in the form of data and forecasts; advisories and warnings of hazardous or destructive weather and hydrological phenomena; and investigations, studies, and research on the hydrometeorological regimes of continental and insular portions of the USSR, of interior bodies of water, and of bordering seas and oceans.

This responsibility entails supplemental investigations, research and development work, and other measures required 1) to adopt new operational techniques, 2) progressively to improve the weather service, and 3) to raise professional standards and skills of weather service personnel. The direction, administration, and maintenance of the Hydrometeorological Service are implemented through a system of central and regional scientific research institutes, central service and liaison organs, and 35 subordinate republic and territorial administrations. These organs are designated as follows on the accompanying chart:

- A, Main Administration of the Hydrometeorological Service.
- B to H, central scientific research institutes in Moscow or Leningrad.
- I to M, regional hydrometeorological scientific research institutes in Vladivostok, Tbilisi, Kiev, Alma-Ata, and Tashkent.
- N to Q, central service and liaison organs in Moscow or Leningrad and associated educational institutions.
- R, subordinate republic and territorial administrations.
- R-1 to R-xvi, field organs (individually designated).
- R-1 to R-xiii, operating field organs (not collectively designated).
- R-xiv to R-xvi, field service and maintenance organs (not collectively designated).

Generally, the system operates as follows:

GUGMS directs and controls the work of all organs in the system and coordinates and standardizes the work of hydrometeorological networks of other Soviet agencies participating in the national service.

The central institutes conduct highly specialized investigations and studies required to provide information and to maintain high standards of service. The regional institutes investigate local problems, provide specialized services that cannot be provided on the national level, and study the hydrometeorological regimes of particular areas more thoroughly than would be possible at the central institutes.

The functions of the Main Aviation Weather Center, the Main Radiometeorological Center, the Hydrometeorological Publishing House, and the educational institutions are described below. The field organs [R-1 through R-xvi] are directly supervised, maintained, and inspected by the subordinate republic and territorial administrations of GUGMS. The principal operating organs [R-1 through R-x] under each of the 35 administrations provide (in addition to observations) forecasts, warnings, and advisories. The other operating organs [R-xi through R-xiii] make simple visual noninstrumental observations. The nonoperating organs [R-xiv through R-xvi] provide service, maintenance, and repair work.

A. Main Administration of the Hydrometeorological Service (GUGMS)

GUGMS is located in Moscow. Its relationship to the subordinate elements of the system has been defined in Paragraph a. In addition, it coordinates and standardizes the work of hydrometeorological networks of other arms of the government which must follow the directives of GUGMS with regard to participation in the national network. For example, the network of stations in the Soviet sector of the Arctic is administered by the Main Administration of the Northern Sea Route, but is under the functional supervision of GUGMS.

GUGMS publishes the monthly scientific journal *Meteorologiya i gidrologiya* (Meteorology and Hydrology).

CENTRAL SCIENTIFIC RESEARCH INSTITUTES

B. Central Institute of Weather Forecasts

The Central Institute of Weather Forecasts (TsIP) is the national scientific research institute and supervisory organ in the field of meteorological and hydrological forecasting. TsIP collects weather reports in coded form from the network of stations under the direct supervision of the 35 republic and territorial administrations. Each synoptic station transmits its report at 0300, 0900, 1500, and 2100 hours Moscow Time to the nearest weather bureau [R-1], which in turn transmits it to TsIP and to the nearest regional radio meteorological center [R-xiv]. The regional centers and TsIP broadcast weather reports at regularly scheduled times; similar reports are also broadcast to non-Soviet radio stations. These reports provide the basic data required for compiling synoptic weather maps for any subdivision of the Service. TsIP also rebroadcasts certain non-Soviet weather reports.

In addition to TsIP, certain major weather bureaus [R-1] issue advisories on the analysis of weather maps and remarks on the prospective development of atmospheric processes. The transmission of facsimiles of analyzed weather maps from TsIP and the weather bureaus is gradually being introduced. TsIP transmits computations of vertical wind velocities and data for compiling 24-hour prognostic weather maps. Weather forecasts for general use are transmitted by radio, telegraph, or telephone to certain organizations according to prior arrangements. TsIP and local weather bureaus also issue and distribute daily weather bulletins, and along with aviation weather stations [R-iv], keep interested organizations informed about special weather phenomena in a given region and transmit advisories or warnings accordingly [9, p. 37]. TsIP has divisions for long-range and agrometeorological forecasting [39, p. 74].

C. Main Geophysical Observatory imeni A. I. Voyeykov

This institution, located in Leningrad, is the principal scientific research arm of GUGMS in all branches of meteorology and climatology. The Main Observatory, currently under the direction of M. I. Budyko, conducts the more comprehensive investigations of physical processes in the atmosphere, studies the climate of the USSR and other parts of the world, and develops methods, procedures, and instruments for making meteorological observations. It issues procedural handbooks and directives for the various units of the Service in the field of meteorology and handbooks for observers at meteorological stations and posts. The *Trudy Glavnoy geofizicheskoy observatorii im. A. I. Voyeykova* (Transactions of the Main Geophysical Observatory) is one of its major publications. [29]

The Observatory has sections or divisions for the following subject areas: dynamic meteorology, physics of the surface layer of the atmosphere, and investigation and modification of local climate. [39, p. 74]

D. State Hydrological Institute

This institute, located in Leningrad, is engaged in investigating the hydrology of the continental USSR and its island possessions. The Institute 1) conducts investigations into the regimes of surface waters of continental and other land masses, such as rivers, swamps, lakes, and reservoirs, 2) develops computing and forecasting methods in connection with problems related to water utilization, and 3) establishes methods of hydrological measurement. Major work in recent years includes a survey of water resources -- through which virgin and abandoned lands are being reclaimed -- the development of a theory and methods of computing water regimes of streams in line with the planning of hydroelectric power stations, and methods of computing the water regime of swamps and marshes.

The Institute has developed a number of automatic hydrological measuring instruments. It publishes *Trudy Gosudarstvennogo gidrologicheskogo instituta* (Transactions of the State Hydrological Institute) and presently is compiling the second edition of *Spravochnik po vodnym resursam SSSR* (Handbook on the Water Resources of the USSR). [30; 31]

E. State Oceanographic Institute

This is the central scientific research institute in the field of marine hydrology. Founded in 1943, its main office is in Moscow, with a branch in Leningrad. The Institute concerns itself with the general laws of physical processes taking place in oceans, seas, and estuaries. It studies the hydrological regime of such water bodies for the purpose of compiling handbooks, forecast information, and data on hydrological regimes for the Merchant Fleet, the fishing industry, and ship-building and associated engineering operations. It is also responsible for the scientific direction of the network of marine hydrometeorological stations [R-viii] and marine observatories [R-ii].

The Institute has seven divisions: Oceanography, Tides, Physics of the Sea, Marine Chemistry Laboratory, Laboratory of Marine Estuaries, Instrumentation, and Methodology. Its principal bases of operation are 1) marine hydrometeorological observatories and specialized maritime stations, 2) marine hydrometeorological stations and posts, 3) estuary hydrometeorological stations, and 4) marine expeditionary research of the Institute itself and of the maritime administrations of GUGMS. Results of investigations by the Institute are published in its *Trudy Gosudarstvennogo okeanograficheskogo instituta* (Transactions of the State Oceanographic Institute) and in monographs and manuals (atlases, handbooks, charts, and tables). [32]

F. Central Aerological Observatory

This scientific research institute engages in research on physical processes in the free atmosphere. It was organized in 1940 and is located at Dolgoprudnaya Station in Moscow. The Observatory studies the regimes of temperature, pressure, humidity, and other meteorological elements and conducts investigations on cloud-forming processes, properties and structures of clouds, transformation of air masses, atmospheric turbulence, radiational processes, and optical properties of the atmosphere. It is working out methods of modifying fog and precipitation, and of utilizing radar for observation of wind, thunderstorms, and other atmospheric phenomena. In its investigations, the Observatory conducts experiments and observations directly in the free atmosphere by means of aerostats, radiosondes, and aircraft. The development of new procedures and the design of new instruments are also a part of the Observatory's comprehensive program of aerological observations. The program includes the direction of the aerological activities of the entire network of hydrometeorological stations. The Observatory's house organ is the *Trudy Tsentral'noy aerologicheskoy observatorii* (Transactions of the Central Aerological Observatory).

G. Scientific Research Institute of Aeroclimatology

Located in Moscow, this institute is the central organ of the Service engaged in the methodology of mechanical data processing in all aspects of meteorology. Analysis and interpretation of processing results are also responsibilities of the Institute. Its house organ is the *Trudy Nauchno-issledovatel'skogo instituta Aero-klimatologii* (Transactions of the Scientific Research Institute of Aeroclimatology).

H. Scientific Research Institute of Hydrometeorological Instruments

Here, new types of instruments are developed and existing instruments are improved. The Institute was founded in 1948 in Moscow and supersedes the former Central Engineering Bureau of GUGMS. There are a number of laboratories, an Engineering Division, an experimental-production workshop, and an experimental hydrometeorological station where instruments are tested. The Institute publishes the *Trudy Nauchno-issledovatel'skogo instituta gidrometeorologicheskogo priborostroyeniya* (Transactions of the Scientific Research Institute of Hydrometeorological Instruments), in which the more important research results in the theory and engineering of hydrometeorological instruments are published. [34]

REGIONAL SCIENTIFIC RESEARCH HYDROMETEOROLOGICAL INSTITUTES

Regional scientific research hydrometeorological institutes have been established throughout the USSR to investigate both general and regional problems in meteorology and its allied branches. Regional institutes have been established in the Soviet Far East, at Vladivostok in 1949 [1]; Kazakhstan, at Alma-Ata in 1951 [J]; the Ukraine, at Kiyev in 1951 [K]; Georgia, at Tbilisi in 1953 [L]; and Soviet Central Asia, at Tashkent [M].

Each of the regional institutes publishes the results of its major research efforts in its *Trudy*, or house organ. The titles of various articles are listed in *Meteorologiya i gidrologiya* at irregular intervals. Very unfavorable reviews of a number of articles first appearing in the *Trudy* of the Kazakh Scientific Research Hydrometeorological Institute suggest that there is considerable, if not complete, autonomy of each institute. [35]

CENTRAL LIAISON AND SERVICE ORGANS

N. Main Aviation Weather Center

The Center, located in Moscow, is an interdepartmental facility and liaison office between the civilian and military weather services. Its Director is Anatoliy V. Brodskiy. In the lead articles of the July 1961 issue of *Grazhdanskaya aviatsiya*, [12], Brodskiy outlines the cooperative measures being taken by the Main Administration of the Civil Air Fleet and GUGMS to modernize preflight and flight weather service. There is very little additional published information on the Center, which was only recently established at Vnukovo Airport.

O. Main Radiometeorological Center

The most powerful radio broadcasting station in the USSR is located at the Center in Moscow. It broadcasts nationally and internationally on a regular schedule. In 1956, there were in addition 26 regional radio meteorological centers [R-xiv]. [36]

P. Hydrometeorological Publishing House

"Gidrometeoizdat" has its main office in Leningrad and a branch in Moscow. It publishes the periodicals, serials, and monographs issued under the auspices of GUGMS and its affiliates, as well as contributions from specialists of other institutes or organizations. [37]

Q. Educational Institutions

Educational institutions have been established to prepare cadres of qualified meteorologists, hydrologists, oceanographers, and agricultural meteorologists on both intermediate and advanced levels for the Service. In 1930, the Moscow (now the Leningrad) Hydrometeorological Institute and the Vladivostok, Moscow, and Rostov

Hydrometeorological Technical Schools were organized. Later, the Khar'kov (now the Odessa) Hydrometeorological Institute and a number of technical schools were organized to keep pace with the rapidly expanding Service. By 1941, over 1000 ^{schools} ~~schools~~ were qualified to ^{give} ~~to give~~ advanced instruction and more than 2000, ^{to give} ~~to give~~ intermediate instruction. In addition, the program to prepare cadres has been broadened by the participation of some of the state universities and by the correspondence courses now being offered to 4500 Service personnel. Some 2240 of these are enrolled in courses from higher educational institutions. Further, many of the rank and file workers in the Service, chiefly observers, are raising their skill levels in hydrometeorological schools. About 11% of all the workers of the Service attend classes annually. [2]

REPUBLIC AND TERRITORIAL ADMINISTRATIONS

R. Republic and Territorial Administrations

The chief responsibility of these administrations consists in providing routine weather service to the national economy in the form of hydrometeorological data, information, and forecasts. Each of the 35 administrations supervises and inspects the work of the station network in its administrative area. Each is charged with the conduct of projects on a regional or local scale and the operational planning and distribution of the basic network of stations and posts required for complete coverage of the area's hydrometeorological regime.

Individual administrations are not indicated on the 1960 organization chart. Republic administrations are maintained in each of the 15 Union Republics, as well as in the former Karelo-Finnish SSR (now a part of the RSFSR). The territorial administrations are located throughout the RSFSR. The following is an alphabetical listing of the geographical designations of the territorial administrations:

Arkhangel'sk
Chita
Gor'kiy
Irkutsk
Kamchatka
Khabarovsk
Kolyma
Krasnoyarsk
Kursk
Kuybyshev

Leningrad
Murmansk
Novosibirsk
Omsk
Rostov
Sakhalin-Kurile Islands
Sevastopol'
Sverdlovsk
Vladivostok
Yakutsk

[1, p. 16; 39, p. 74]

R-1. Weather Bureaus

The collection, transmission, and dissemination of data on current (and sometimes on past) weather conditions are the principal duties of the weather bureaus. In addition, the bureaus compile and disseminate weather forecasts of various ranges, forecasts conforming to requirements of each of the administrative units, and forecasts for other special purposes. [9, p. 47]
The bureaus have a staff of synoptic meteorologists, and forecasting

is the major function of most of these stations. The bureaus are frequently located in the principal cities or capitals of the various administrative regions [40, p. 58]. Articles written by specialists at weather bureaus appear in *Sbornik po sinoptike* (Collection of Articles on Synoptic Meteorology) and in the *Trudy* of the regional scientific research hydrometeorological institutes.

R-11. Observatories

The responsibilities of the observatories include the performance of synoptic observations of all meteorological elements, the continuous recording of changes in the basic elements, and the conduct of highly specialized observations and investigations related to the region which they serve [40, p. 213]. For example, the Tashkent Scientific Research Observatory has conducted important investigations of the climate of Soviet Central Asia and has taken steps to develop or improve methods of forecasting weather and agrometeorological conditions in cotton-growing areas. It also makes very detailed actinometric observations. The marine observatories on the other hand specialize in the observation and forecasting of phenomena in coastal and sea areas.

R-111. Hydrometeorological Bureaus

These are organized especially for making forecasts, storm warnings, and advisories for agriculture. They issue 10-day summaries of past weather conditions and prepare resumes of crop conditions within their administrative regions. For example, the Yaroslavl' Hydrometeorological Bureau serves 247 organizations, including 97 collective farms and 15 state farms. The results of work in the bureaus are published in *Sbornik po sinoptike* and in the *Trudy* of regional scientific research hydrometeorological institutes. [39, p. 72; 41]

R-iv. Aviation Weather Stations

Located at airports of the Civil Air Fleet, the aviation weather stations make meteorological and aerological observations, collect weather reports, compile and analyze synoptic and upper-air maps, and provide detailed aviation weather data and information to aircraft crews at preflight briefings and during flight. A special

feature of the service is the compilation between issues of standard synoptic observations of special large-scale dense-network synoptic maps of local areas during deteriorating weather conditions.

At present, aviation weather service in the USSR is being modernized to serve the requirements of high-speed and high-altitude aircraft more efficiently. Attempts are being made to incorporate into routine operations such modern techniques as radar and automatic recording and broadcasting from radiometeorological stations. For example, the installation of copying machines will soon make obsolete the hand-copied *Pilots' Bulletin*, which will be replaced by duplicates of current synoptic maps and other meteorological information. Improvements will also be made in in-flight weather service. [12-16; 18-19]

R-v. Meteorological Stations

Here, hydrometeorological observations are made on a regular schedule throughout the year. Each republic and territorial administration of the Hydrometeorological Service is responsible for selecting the sites for individual stations within its network. Site selection is governed by degree of exposure to prevailing elements, proximity to populated places, and accessibility.

The stations are of three orders. First-order stations make standard synoptic observations and continuous recordings of variations of the basic elements and specialized observations as required. The last include actinometric, aerological, and atmospheric-electricity observations. First-order stations have a minimum staff of nine persons to maintain the basic program, and additional personnel are assigned for the special projects. The program for first-order stations encompasses the following:

Standard Synoptic Observations

visibility
cloud formation
icing
precipitation
temperature
wind conditions
pressure
humidity
soil temperature

Hydrological Observations

water-table levels
alluvial discharge
chemical compositions in water

With additional personnel:

water temperatures
ice phenomena
stream levels
evaporation

Some first-order stations also undertake pilot-balloon and radio-sonde observations. [43, Appendix]

Second-order stations perform the same routine synoptic and hydrological observations as first-order stations with minimum staff. Specialized observation work is not undertaken by these stations. The minimum staff of second-order stations consists of four to five persons. Third-order stations are staffed by at least two persons and do much the same work as second-order stations.

R-vi. Hydrological Stations

Routine operations at these stations are similar to those of first- and second-order meteorological stations. The complete hydrological observation program (with augmented staff) includes observation of water temperature, ice phenomena, state of water surfaces, alluvial discharge, chemical compositions in water, and evaporation from soil and water surfaces. First-order stations have a minimum staff of seven persons; second-order stations, of three to four.

R-vii. Aerological Stations

The meteorological, hydrological, and agrometeorological programs for minimum staffs of aerological stations are the same as for first- and second-order meteorological stations. The aerological program at all stations includes radar soundings and radiosonde and pilot-balloon observations. First-order stations with staff additions undertake specialized investigations and operations within the aerological program. First-order stations have a minimum staff of 23 persons; second-order stations have a minimum of 19. It should be noted that hydrological and aerological stations do not make specialized agrometeorological observations.

R-viii. Marine Hydrometeorological Stations

First- and second-order station programs are similar to those of first- and second-order meteorological stations. Third-order stations do not conduct aerological or agrometeorological observations. Additional elements of the program at marine hydrometeorological stations are measurements of the specific gravity of water (normal staff) and, at first- and second-order stations

only, the taking of hydrological cross sections, ice profiles, and roadstead observations. Minimum staff complements are ten to eleven, five to six, and three persons.

R-ix. Special Programs

Runoff stations have a program similar to first-order hydrological stations. Agrometeorological stations operate observation programs for all agrometeorological elements and have a general program similar to that of second-order meteorological stations. Estuary and lake stations have programs of work similar to those of first-order marine hydrometeorological stations, with the exception of specific gravity measurements. Bog stations have a program of observations similar to runoff stations for swamp and marsh areas. Microseismic observations are made according to requirements of certain special programs.

R-x. Ship [Marine-Weather] Hydrometeorological Stations

First-order stations with minimum staff observe atmospheric phenomena, visibility, cloud cover, wind, air temperature, pressure, and humidity in their meteorological programs; pilot-balloon observations in their aerological program; and water temperature, ice phenomena, state of water surface, and specific gravity of water measurements in their hydrological program. With supplemental staff, radiosonde observations are made. At second-order stations, similar meteorological and hydrological (except specific gravity of water) programs are observed. Pilot-balloon observations are authorized with a supplemental staff. Third-order stations have the same meteorological and hydrological programs as the second-order stations. Measures are now being taken to improve the quality and the areal extent of the ship reporting service, which until recently was very poor. [44]

R-xi. Meteorological Posts (Formerly, Third-Order Stations)

First-order posts perform observations of weather phenomena requiring little instrumentation, such as visibility, cloud conditions, precipitation, snow cover, and water-table levels. First-order posts also undertake complete or partial agrometeorological

observation programs. The duties of second-order posts are substantially the same as those of first-order posts, except that only partial agrometeorological programs are conducted. Third-order posts perform no agrometeorological functions at all.

R-xii. Hydrological Posts

First- and second-order hydrological posts observe the same meteorological elements as meteorological posts. No agrometeorological or aerological functions are performed. Hydrological elements observed are water temperature, ice phenomena, state of water surfaces, surface stream levels, water-table levels, alluvial discharge, and chemical composition of water. At third-order stations only water temperature, ice phenomena, and surface stream and water-table levels are observed.

R-xiii. Agrometeorological Posts

Observations of atmospheric phenomena and precipitation and snow-cover measurements are made here.

R-xiv. Radio Meteorological Centers

In 1956 there were 26 regional radio meteorological broadcasting centers in various parts of the USSR. [36]

R-xv. Repair and Maintenance Crews

These are under the jurisdiction of the republic and territorial administrations [38, p. 298].

R-xvi. Instrument Calibration Bureaus

These offices are under the jurisdiction of the republic and territorial administrations, but operate under directives of the Main Geophysical Observatory imeni A. I. Voyeykov.

Marine Hydrometeorological Posts

With a minimum staff of one, these posts have no aerological and agrometeorological programs. All three orders observe atmospheric phenomena, visibility, cloud conditions, temperature, wind conditions, water temperature, and ice phenomena. Snow cover and precipitation are measured at first- and second-order posts. First-order posts also observe surface stream levels and water-table levels. [43, Appendix]

Health-Resort Administration

*Should be found under
allied organization*

This administration maintains a number of stations at health resorts in the Crimea, the Caucasus, the Transcaucasus, and the Transbaykal. [14, p. 22]

ALLIED ORGANIZATIONS

The Institute of Physics of the Atmosphere, Academy of Sciences USSR, is engaged in the study of physical properties of the atmosphere and the processes taking place in it. Established in 1956, the Institute has two divisions: one for research on the upper atmosphere, and one for turbulence studies. Laboratories for atmospheric acoustics and atmospheric optics are maintained. The Institute has a branch at Zvenigorod, Moscow Oblast, and three stations: the Severnaya, on the Kola Peninsula south of Murmansk; the Roshchinskaya, on the Karelian Isthmus in Leningrad Oblast; and the Tsimlyanskaya, on the shore of the Tsimlyanskiy Reservoir in Rostov Oblast. Chief tasks of the Institute are studies of 1) processes in the various layers of the atmosphere, 2) optical properties of the atmosphere, 3) atmospheric turbulence, and 4) certain aspects of weather-forecasting theory. [47]

The Department of Physical Geography, Institute of Geography, Academy of Sciences USSR, makes general and regional studies in meteorology, climatology, and hydrology. Its *Trudy* publishes the results of the more important investigations in these fields. Many of the Department's staff are authors of monographs on regional topics containing chapters pertaining to the meteorological sciences. The Institute has 12 divisions, including the Divisions of Climatology, Hydrology, Limnology, and Glaciology. [14, p. 15]

The Institute of Cryology imeni V. A. Obruchev in Moscow conducts research on the physics, chemistry, thermo-physics, and mechanics of permafrost and snow. The Institute has a Northern Branch at Vorkuta and a Siberian Branch at Yakutsk. In addition, the Institute operates three permafrost stations: Igarskaya, Aldanskaya, and Anadyrskaya. [47]

The Institute of Oceanology, Academy of Sciences USSR, conducts investigations of seas and oceans. It has a Laboratory of Marine Meteorology. Its house organ is the *Trudy Instituta okeanologii AN SSSR* (Transactions of the Institute of Oceanology). [47]

The Joint Meteorological Computing Center (Ob'yedinennyy meteorologicheskiy tsentr) was established in 1960 to develop electronic methods of weather forecasting. Its director is P. K. Yevseyev. [48]

Moscow State University has a Department of Climatology and a Department of Geography of Northern Polar Stations. It maintains Khibinskaya geograficheskaya stantsiya, a research post, and the Snow and Ice Laboratory. The University's *Uchenyye zapiski* occasionally publishes issues on climatology, as does the *Vestnik, Seriya geograficheskaya*.

The Main Administration of the Northern Sea Route controls the network of hydrometeorological stations in the Soviet Arctic located generally east of the Barents Sea, with stations on Franz Josef Land and at Barentsburg, Spitsbergen. The Arctic and Antarctic Scientific Research Institute is the Administration's chief research arm. In 1959, the Arctic and Antarctic Scientific Research Institute had the following divisions: the Geophysical Division, with Aerological and Actinometric Sections; the Division of Polar Stations; and the Division of Meteorology and Weather Forecasting (in Leningrad). The Moscow Branch of the Institute has a Division of Meteorology and Weather Forecasting with a Climatology Section headed by I. M. Dolgin.

Educational institutions of the Main Administration of the Northern Sea Route providing meteorological training are the Higher Arctic Marine School imeni S. O. Makarov, which has a Department of Hydrometeorology, and the Leningrad Arctic School, which has an Aerology Division (established in 1956) and the Meteorological Instruments, Aerological, and Geophysical Laboratories (established in 1960).

The Institute of Mathematics and Mechanics, Academy of Sciences Uzbek SSR, has conducted many investigations on the regional synoptic meteorology of Soviet Central Asia [50].

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SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR)
Report 1. Paragraph 1-a

SOURCE : Zolotukhin, A. A. Forty years of the Soviet Hydrometeorological Service. Meteorologiya i gidrologiya, no. 6, Jun 1961, 3-12.

On 21 June 1921, V. I. Lenin signed a decree of the Council of the People's Commissars of the Russian Soviet Federated Socialist Republic (RSFSR) establishing a meteorological service in the RSFSR. The increase from 200 meteorological stations and 125 precipitation gage posts in 1920 to 20,000 stations of all kinds by 1 January 1961 gives some idea of the expansion and growing complexity of the national weather service. During 1921-1929, the Main Geophysical Observatory did much of the preliminary work involved in setting up the Hydrometeorological Service, but its limited resources and capabilities could not meet the demands of the rapidly growing economy.

By 1929, there were twelve different departments providing meteorological and hydrological services in the USSR. To a great extent, all of these operated independently and without coordinating such important matters as planning and developing the meteorological and hydrological networks, equipping stations with standard instruments, publishing data in a standardized format, organizing a unified information service, investigating the climates of the USSR, establishing storm warning and advisory services, and organizing a weather forecasting service for agrometeorological and hydrological conditions.

On 7 August 1929, the Central Executive Committee and the Council of the People's Commissars of the USSR adopted a resolution recommending the consolidation of the country's meteorological and hydrological services. The Hydrometeorological Committee of the RSFSR formed by this resolution was expanded in 1932 to include all the other Soviet republics and lesser political units. The supervision of all meteorological, hydrological, and geomagnetic work in the country was delegated to the Hydrometeorological Committee. The first director of the Hydrometeorological Service, A. F. Vangengeym, is credited for much of the consolidation.

During 1929-1932 the Main Geophysical Observatory carried out a great deal of work and published several volumes on the climate of the USSR. A central weather forecasting service, the Central Weather Bureau, began to issue short- and long-range forecasts and later to broadcast them by radio. Under the direction of B. P. Mil'tanovskiy, investigations in the field of long-range weather forecasts were conducted. Also at this time, the Moscow Aerological Observatory made a systematic study of the atmosphere by means of meteorographs attached to kites and aircraft. On 30 January 1930, the world's first radiosonde, designed by P. A. Molchanov, was released. Its design was found to be so satisfactory that with certain modifications it is still in use.

The agrometeorological service was created by P. I. Braunov, originally to make summaries of weather conditions every ten days and record the date of new phases in crop development and current crop conditions. The Russian Hydrological Institute was revived and later renamed the State Hydrological Institute, which was to become the country's central scientific research organization in the field of hydrology. Hydrologic investigations performed at this institute

under the direction of V. G. Glushkov formed the basis for the future development of hydrology as an independent science. During these same years, hydrologic forecasts were first issued.

In 1929, the State Oceanographic Institute was established for the purpose of planning oceanographic research.

The period from 1930 to 1940, when all branches of the national economy were developing rapidly, was a very important one in the development of the Hydrometeorological Service. The increased requirements of the expanding economy made another reorganization necessary and on 14 November 1936 the Main Administration of the Hydrometeorological Services of the USSR was established by government decree. By this decree, the administration was given the responsibility for the overall study of the hydrometeorological conditions of the USSR and for providing weather service for the national economy and defense. The favorable conditions created for the administration resulted in its rapid development. The weather service, headed by the Central Weather Institute, was consolidated and programs in the hydrometeorological service for agriculture, civil aviation, rail and sea transport, and other branches of the national economy were initiated and gradually expanded. Considerable progress was made in scientific research projects and in the summarization and publication of data on meteorological conditions in the form of annual reports, handbooks, atlases, etc. Among these are included such fundamental works as the *Klimaticheskiy spravochnik SSSR* (Climate Handbook of the USSR) and *Vodnyy kadastr SSSR* (Water Register of the USSR).

By 1941, the Hydrometeorological Service of the USSR was a huge and well-organized scientific operational establishment comprising 29 local and republic administrations, major scientific research organizations, advanced and intermediate hydrometeorological schools, plants for manufacturing hydrometeorological instruments, more than 200 operating divisions of the weather-forecasting service (weather bureaus, hydrometeorological bureaus, aviation meteorological stations), and more than 6000 hydrometeorological stations and precipitation gage posts.

The war with Germany interrupted the country's peacetime progress, including that of the hydrometeorological service. During World War II, the hydrometeorological service was incorporated into the People's Commissariat of Defense and its activity was directed chiefly by the requirements of the national defense. For its effectiveness during the war and the harmonious relations which were maintained between officers and civilians throughout this period, some 800 workers in the hydrometeorological service received military orders and medals.

In February 1946, the Central Administration of the Hydrometeorological Service of the Soviet Army was once again organized along prewar lines. The work of adapting the hydrometeorological service to the needs of the defense effort during the war and of converting it back into an organization concerned with peacetime problems was done under the direction of Ye. K. Fedorov.

The chief task in the early post-war years was the reestablishment of the hydrometeorological services destroyed by the German occupation forces. In a short time, some 600 hydrometeorological stations and more than 1500 precipitation gage posts had been set up in formerly occupied areas. At the same time, new posts and stations were established or increased in number in areas hitherto poorly represented. The distribution of stations was made in accordance with scientific principles developed by the Main Geophysical Observatory, the State Hydrological Institute, and the State Oceanographic Institute, and was designed to provide the maximum possible coordination of observations on meteorological, hydrological, aerological, and agrometeorological regimes.

The 15-year period of 1945 to 1960 was one of great expansion. Some 6000 agrometeorological and 1298 hydrometeorological stations plus 5600 precipitation gage posts were added to the national network. This expansion was greatest in the Asiatic part of the USSR, where the number of hydrometeorological stations increased 88% and the precipitation gage posts by 176%. In the country as a whole, the number of stations observing precipitation increased three times; subsurface soil temperature, five times; soil moisture, 2.6 times; run-off, 2.3 times; actinometric conditions, 10 times.

Observations of evaporation from both soil and water surfaces have greatly expanded. Run-off and bog stations have been organized for studying the formation of run-off and specialized hydrometeorological observatories and lake stations established for conducting studies of the hydrometeorological regime of the large reservoirs.

The growth of the aerological network, especially in aviation weather forecasting, is a good indication of the expansion of specialized services in recent years. When Lenin signed the first organization decree in 1921, virtually no routine aerological observations were being made. By 1923, the aerological network had 15 pilot-balloon(pibal) stations, two aircraft meteorograph sounding stations, and several kite-meteorograph stations. In 1930, the number of pibal stations had increased to 30 and the use of radiosondes had been initiated. Since then the use of balloon-sonde and kite-meteorograph has greatly diminished. By 1941, there were 40 radiosonde and 273 pibal stations in the national network, and rawin observations were begun in 1943.

Soon after the war, the development of aerosynoptic analysis raised the problem of significantly increasing the number of stations making temperature-wind soundings. It was decided to create a network of special aerological stations fully equipped with all necessary instruments, including radar. By 1961, 140 major aerological stations were in operation, and a network was being organized to detect thunderstorms and heavy showers by radar and to provide aviation storm warnings.

During the 1950's, the introduction of meteorological rockets for the study of the stratosphere opened a new stage in aerological investigations. The development of high-speed aircraft made it necessary to improve the radiosonde and rawinsonde. Much success was achieved in raising the ceiling and improving the quality of observations of radiosonde, and by now the network has been completely reequipped with modern instruments. The "veteran" Molchanov radiosonde has been replaced by an instrument which provides semiautomatic reception of data and allows much higher operational ceilings. From 1946 to 1960, the mean radiosonde ceiling for the entire network rose from 9 km to 22 km. At present, additional measures are being taken to expand the aerological network and to equip it with still more modern equipment.

Expeditions and investigations into special subject areas have greatly increased in recent years. So far more than 500,000 km of the country's rivers have been explored hydrographically. Many changes have been made in methods of aerial reconnaissance of rivers and reservoirs (especially in late winter), in methods of aerial reconnaissance of ice conditions and weather, and in methods of taking soundings of the atmosphere. Traverse surveys of the snow cover in Soviet Central Asia and the Caucasus Mountains are now being made; the number of expeditionary investigations on seas and oceans is increasing; major expeditionary projects are being conducted in the lands of Kazakhstan and the Altay; and microclimatic and aerological investigations are in progress in Povolzh'ye, Kazakhstan, and other parts of the country. The hydrometeorological service has been placing great emphasis on expeditionary explorations because they provide the necessary preliminary information about little-known areas of land and water in a short time.

The accumulation of huge amounts of raw observational data every year makes the processing and publication of the results of these observations one of the major responsibilities of the Hydrometeorological Service. At present, more than 5000 pages on the hydrometeorological regime are published annually. Hundreds of millions of cards are punched for processing in electronic analytical computers, and photo-offset printing shops have been established in the branches of the Service in order to speed up the publication of hydrometeorological data. In addition, basic works such as ~~the Klimaticheskiy spravochnik SSSR (Climate Handbook of the USSR) in 27 volumes~~, climatic descriptions of the European, Far Eastern, and other parts of the USSR, meteorological handbooks, atlases, agroclimatic handbooks on the agriculturally most important krais and oblasts, and annual hydrological reports are being published. At present, a Spravochnik po vodnym resursam SSSR (Handbook on the Water Resources of the USSR) and a second revised edition of the Klimaticheskiy Handbook of the USSR are being compiled.

In the preparation of publications on regime data and in the expansion of the network of posts and stations, the republic and territorial administrations of the Hydrometeorological Service and their hydrometeorological observatories play the decisive role.

SOURCE : Zolotukhin , A. A. Forty Years of the Soviet Hydrometeorological Service
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Paragraph 1 :

Page 4 paragraph 3 line 8 to end should read :

In addition, basic works such ~~handbooks~~ as climatic descriptions of the European, Far Eastern and other portions of the USSR, meteorological handbooks, atlases, agroclimatic handbooks on the agriculturally most important krais and oblasts, and annual hydrological reports are being published. In addition, second revised editions of Spravochnik po vodnym resursam SSSR (Handbook on the Water Resources of the USSR) and Klimaticheskiy spravochnik SSSR (Climatic/~~net~~ Climate⁷ Handbook of the USSR) are being compiled.

After the Second World War, the rapid development of all branches of the national economy made greater specialization in the requirements of each branch necessary. For instance, at all airports of the Civil Air Fleet, aviation meteorological stations have been set up to serve the flights directly.

The specific requirements of recently developed large high-speed aircraft have prompted basic changes in the meteorological service. The radiosonde network has been expanded; the number of observations has been increased to three or four a day; instruments and procedures for measuring cloud ceilings and visibility have been improved; a radio-teletype network has been established for the rapid transmission of meteorological reports and facsimiles of synoptic maps; and the forms used in the aviation service have been changed. Among many other improvements that have been initiated are 1) the special efforts which have been made to provide service along flight routes and to investigate flight conditions for high-speed aircraft in the troposphere and the lower stratosphere, 2) the creation of major aviation centers, and 3) the overall improvement of communications and the system of collecting and distributing meteorological reports and information.

For serving agriculture, special hydrometeorological bureaus have been organized in the krais and oblasts; for serving hydroelectric power operations and the river fleet on the reservoirs there are specialized observatories; for the fishing industry's ocean ports, special operating groups have been set up.

The growth of the weather-forecasting service can be illustrated by the following statistics. In 1946, the weather and hydrometeorological bureaus compiled a total of 150,000 24-hour forecasts and special weather warnings, while in 1960 the number reached 600,000. The number of three-day forecasts increased from 6000 to 82,000. The five- to seven-day forecasts rose from 4000 to 26,000. During this period, verification of weather forecasts and storm or special weather warnings improved somewhat but not enough to satisfy the demands of the national economy. This is especially true for the long-range forecasts.

During the last 10 to 12 years, there has been a great increase in the demand for agrometeorological forecasts and data. To meet this demand, the Central Institute of Weather Forecast is providing 34 weather bureaus under the various administrations of the Hydrometeorological Service, 116 oblast hydrometeorological bureaus, and more than 1000 agrometeorological and 2500 hydrometeorological stations. Operative organs of the Service systematically compile ten-day agrometeorological bulletins, agrometeorological forecasts of agricultural production conditions, reports of crop growth and development, and five-day résumés of agricultural production conditions. Special agricultural reports are issued during periods of unusually favorable or unfavorable weather conditions. All of this makes it possible for farmers to take the necessary protective measures against adverse weather conditions and to exploit especially favorable conditions to the maximum degree.

Hydrometeorological stations are now serving agriculture in a great number of ways. Besides current information on the weather, local kolkhoz and sovkhos establishments and state and party organs are provided with longer range weather forecasts (which the stations receive by radio), frost warnings

(compiled by the stations themselves), weather information for the present and previous 24-hour periods (temperature of the air and soil, wind data, precipitation, humidity), meteorological and agrometeorological information for the ten days just ended (air and soil temperatures, amount of precipitation, humidity, wind, state of soil surface, depth of frost penetration, depth of snow cover, phases of crop development, productive moisture in the soil, results of fruit and winter crop cultivation, temperature sums from the beginning of the growing period), and concise agroclimatic data gathered from the region served by the station.

Services to agriculture are expanding yearly, and special services have been organized for cotton crops, sheep grazing, cattle grazing, industrial crops, viniculture, and subtropical cultures. In response to resolutions of the January Plenum of the Central Committee of the Communist Party, the Main Administration of the Hydrometeorological Service has developed and is putting into operation additional measures for improving hydrometeorological and agrometeorological services to agriculture, especially at the kolkhos and sovkhoz levels.

Before the October Revolution, there were virtually no hydrologic forecasting services. Only in 1922 did the Russian Hydrologic Institute begin to compile forecasts for stream water levels during the spring high waters at many points along major rivers of the European USSR. The 1929-1930 period, when the Unified Hydrometeorological Service of the USSR was established, is considered the beginning of the present hydrologic forecasting service in the USSR. A Hydrologic Forecast Division, which was organized in the former Central Weather Bureau, still operates in the Central Institute and in weather bureaus of the local administrations.

The number of rivers for which hydrologic forecasts are issued has increased from 550 in 1946 to 830 in 1960, and the number of forecasts has reached 10,000 a year. For short-range forecasts, the number of streams has increased from 219 in 1946 to 384 in 1960, and the number of forecasts has reached 100,000 a year. At present, 85 organs of the Hydrometeorological Service conduct hydrologic forecasts. In addition, the number of hydrologic stations has increased, and the forecasts have improved.

Forecasts of the volume of water per month and per vegetation period are now issued for irrigation purposes along most of the rivers of Soviet Central Asia, Kazakhstan, and the Transcaucasus. Forecasts of phenomena hazardous to construction operations have been made in connection with the resumption of the building of huge hydroelectric power stations on the Volga, Kama, Don, Dnepr, Angara, Ob', and other rivers. Hydrologic forecasts have now become the primary instrument in planning the generation of hydroelectric power at hydroelectric stations. Hydrologic forecasts are also used for determining the beginning and ending of the navigation season, for assuring river ship navigation safety on major waterways, and for preventing floods.

Hydrologic forecasts, especially long-range forecasts, do not always satisfy present needs because of the inaccuracy of the forecasting methods. Scientists in the Central Institute of Forecast, the State Hydrological Institute, and some regional scientific research institutes are working on improvements.

Marine hydrometeorological forecast is the most recently established service. During the post-war years, it has developed at a rapid pace. Now on all seas of the USSR, the merchant marine and the fishing industry are supplied with daily forecasts on sea surface conditions, and with both long- and short-range forecasts on ice conditions. In the chief industrial regions, long- and short-range forecasts are made of surface water temperatures. The problem of serving the winter fleet and the fishing industry with information on current marine ice conditions, including conditions in extensive areas of the Sea of Okhotsk and the Barents Sea, has been successfully solved.

The previous concentration of hydrometeorological establishments in Leningrad and Moscow has been corrected over the past ten years with the establishment of five regional complex hydrometeorological scientific research institutes at Vladivostok, Alma-Ata, Tashkent, Tbilisi, and Kiev. The Scientific Research Institute of Aeroclimatology and its branch at Novosibirsk and the Scientific Research Institute of Hydrometeorological Instrumentation have also been established.

The computer and electronic techniques which are now available to the Hydrometeorological Service will be instrumental in accelerating the solution of forecasting and other important and difficult scientific problems. Aerological investigations, climatic and aeroclimatic works, and investigations in the field of hydrologic forecasts are being conducted on a broad front. The Hydrometeorological Service's expeditionary fleet for hydrologic studies of oceans, seas, and estuaries of major rivers has been greatly expanded, and notable progress has been made. Much has been accomplished, especially by the Scientific Research Institute of Hydrometeorological Instrumentation, in creating new improved hydrometeorological instruments for the proper outfitting of meteorological stations and research operations.

The following are some of the scientists in addition to those already mentioned who have contributed to the development of the Hydrometeorological Service: B. P. Alisov, Ye. N. Blinova, M. I. Budyko, V. A. Bugayev, G. Ya. Vangengeym, V. A. Dzherdzhio, B. L. Dzerdzeyevskiy, O. A. Drozdov, N. N. Kalitin, I. A. Kibel', I. Ye. Kochin, V. N. Obolenskiy, S. T. Pagava, Kh. P. Pogosyan, P. N. Tverskoy, A. A. Fridman, S. P. Khromov, B. A. Apollov, Ye. V. Bliznyak, M. A. Velikanov, D. I. Kocherin, A. V. Ogiyevskiy, D. L. Sokolovskiy, N. N. Zubov, L. F. Rudovits, Yu. M. Shokal'skiy, V. V. Shuleykin, L. N. Babushkin, R. E. David, F. F. Davitaya, P. I. Koloskov, S. A. Sapozhnikova, and G. T. Selyaninov.

The education and raising of the skill level of specialists and their proper placement have been and continue to be a prime consideration in the work of the Service.

During the revolutionary and the early Soviet periods, scientific institutions did not offer specialized courses in hydrometeorological subjects. Specialists in the Hydrometeorological Service at that time obtained their education in related fields; for example, meteorologists were geography majors, and hydrologists were majors in communications and hydrotechnical engineering. In 1930, the Moscow (now the Leningrad) Hydrometeorological Institute and the Vladivostok, Moscow, and Rostov hydrometeorological technical schools were organized for preparing cadres of qualified meteorologists, hydrologists, oceanographers, and agricultural meteorologists at both advanced and intermediate levels for the rapidly developing Hydrometeorological Service. Later on, the Khar'kov (now the Odessa) Hydrometeorological Institute and a number of technical schools were organized for the same purpose, so that by 1941 over 1000 persons had acquired advanced levels and more than 2000 intermediate skill levels. In addition, the program of preparing cadres has been broadened in the state universities, and correspondence courses are being taken by 4500 of the Hydrometeorological Service's personnel -- 2240 of them from more advanced scientific institutions. Many of the rank and file of the Service, chiefly observers, are raising their skill levels in hydrometeorological schools and other institutions. Ten to twelve percent of all the workers in the Hydrometeorological Service annually attend these schools.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph a

SOURCE: Belousov, V. M., and S. M. Sadovskiy. The necessity for correct evaluation of meteorological conditions. Vestnik vozdushnogo flota, no. 12, 1960, 45-46.

It was pointed out that listening to meteorological forecasts before takeoff is not enough. The pilot himself must be able to evaluate weather conditions on the basis of data supplied by the meteorological service, correctly determine flying conditions at different altitudes, and skillfully apply this information to the successful completion of his assignment.

To insure meteorologically safe flying conditions, surface weather maps (synoptic, operational, and special large-scale detailed aviation maps) are now supplemented by isobaric surface maps indicating the distribution of weather elements to considerable heights, altitudinal tropopause maps, maps showing maximum wind velocity by individual atmospheric layers, vertical cross section maps, and other supporting material.

A study of meteorological conditions usually begins with analysis of synoptic, operational, and large-scale aviation maps. With these tools it is always possible to determine actual weather conditions for any point or any region along the route at any particular moment and to anticipate expected changes in the weather by determining the nature and behavior of air masses, pressure systems, frontal boundaries, and related phenomena.

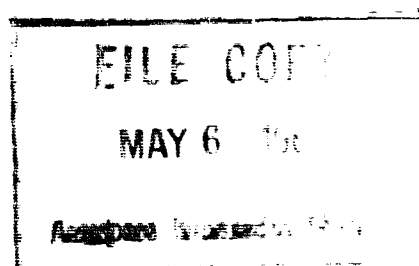
The analysis of surface weather maps, however, provides only a partial picture of prevailing weather conditions. To obtain a complete picture of the lower atmospheric layer, these maps must be supplemented by aviation and radar weather-reconnaissance data.

However, predictions of flying conditions at great altitudes cannot be based on these data alone. Without knowing the altitude temperature distribution and the speed of flight, it is impossible to determine in advance at what altitudes icing will occur; without altitudinal data on the direction and velocity of the wind, it is difficult to correctly diagnose jet streams and turbulence which may prevail at certain altitudes.

All this additional information may be obtained by the commanding officer and flight crew by analysis of altitudinal,

aerological, and particularly cross section maps, which when used in combination complete the information gained from surface and altitudinal maps, weather reconnaissance, and synoptic and aerological material of the meteorological service.

A thorough study by commanding officers and flight crews of prevailing meteorological conditions, coupled with the continuous visual and instrumental evaluation of weather conditions during flight, make it possible to arrive at correct decisions and to eliminate flight accidents and the factors contributing to them.



SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph a

SOURCE: From the obituary of Georgiy Yakovlevich Vangengeym. *Meteorologiya i gidrologiya*, no. 12, 1961, 59-60

The close cooperation between civil and military personnel in meteorological operations is well illustrated by the career of G. Ya. Vangengeym, who died 19 August 1961. During the siege of Leningrad, Vangengeym, who developed the macrocirculation method of long-range hydrometeorological forecasting, was head of a scientific and operational group in the State Hydrological Institute, which serviced the operations of the Leningrad and Northwestern fronts. Later, he was a professor at the Military Hydrometeorological Institute and also worked in the Main Aviation Meteorological Center of the Air Force. From 1945 until recently, Vangengeym was a professor at the Department of Hydrometeorology of the Air Force Engineering Academy imeni A. F. Mozhayskiy. During this time, he also worked in the Arctic and Antarctic Scientific Research Institute as the head of the section on long-range weather forecasting.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph d

SOURCE: Khrabrov, Yu. B. Metodika sostavleniya prognozov pogody na 3-7 dney (Methods of compiling 3-7-day weather forecasts). Moskva, Gidrometeoizdat, 1959, 181 p.

An extensive exposition is presented of the methods and techniques of 3-7-day forecasting based on the analysis of synoptic processes in the upper planetary frontal zones during natural synoptic periods. Recommendations are made for weather forecasting by trajectories of cyclones and anticyclones in various upper planetary frontal zones.

The author states that reliable long-range weather forecasting is a prerequisite for agrometeorological, marine, and river-ice forecasting, etc. Weather forecasts for 3-7 days can be of decisive importance for numerous branches of the national economy. A few illustrations will serve to demonstrate this. A timely prediction of ice formation will prevent damage to the small wooden fishing vessels commonly used by the fishing trade in the Northern Caspian. Hydrometeorological services are equally important to those engaged in range livestock breeding. The great losses sustained as a result of bad weather can be avoided if early warnings are given. Of great importance also is the frost-forecasting service. This is particularly true for the southern cotton and citrus regions. Great sums of money can be saved if accurate predictions of the onset of frost are made.

The use of long-range forecasting has thus far not proved overly useful to the national economy. The main reason for this has been the unreliability of the 3-7-day forecasts. Therefore, the basic task for research in this field should be to increase the reliability of long-range forecasting. Since 1946 the Hydrometeorological Service of the USSR has been using the same synoptic methods for compiling 3-7-day forecasts. These methods are now rather obsolete. It should be kept in mind, however, that the physical principles of the synoptic method of long-range weather forecasting have not yet been sufficiently defined.

In 1956-1957, the author undertook the task of devising new methods of 3-7-day forecasting. For this purpose, he utilized the basic findings of B. P. Mul'tanovskiy and his students; also taking into consideration the recent progress made in synoptic and dynamic meteorology. Mul'tanovskiy originated the method of macrosynoptic analysis. He broke down the chaotic interlacing of the trajectories of cyclones and anticyclones into constituent parts in the form of defined clusters of anticyclonic trajectories and connected regions of cyclonic activity. Mul'tanovskiy's fundamental hypothesis, on which the

macrosynoptic method of long-range forecasting is based, is that Europe's weather is a reflex of centers of action of the atmosphere. Lacking sufficient meteorological data on the atmospheric action centers in the Arctic and Azores regions, Multanovskiy had to judge the state of those centers by the direction of shifting and the frequency of intrusion into Europe of anticyclonic baric formations, which developed in the regions of the above-mentioned action centers.

Analysis of the possibilities in forecasting the evolution of processes during synoptic periods leads to the following conclusions. The techniques of compiling weather forecasts several days in advance can be divided into two stages. The first stage consists in the prediction of the type of synoptic processes and of their evolution during the time period for which the forecast is compiled. This includes the forecast of the general character of the evolution of the synoptic processes, as well as the prediction of the trajectories and shift velocities of the concrete baric formations. It is particularly important to foresee correctly the trajectories of those baric formations which have an immediate effect on the weather of a given region. The second stage comprises the compilation of the weather forecast itself, i.e., compilation of the foreseeable values of meteorological elements and their changes in time.

The position of the upper planetary frontal zones is the most important characteristic feature of circulation in the middle latitudes and reflects the basic features of the synoptic process (regions of the most significant advection of heat and cold, basic regions of cyclogenesis and anticyclogenesis). In studying the evolution of the upper planetary frontal zones, we can learn the position of the basic altitudinal baric formations and their shifts, the degree of zonal or meridional trend of synoptic processes, the number of long waves within the limits of the northern hemisphere, and other factors important for the state of circulation.

The present monograph unites the reports made by the author on the first phase of the development of methods for the analysis and prognosis of the general character of macroscopic processes for 3-7-day periods.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph d

SOURCE: Khromov, S. P. On the present state of Soviet climatology. *Zeitschrift für meteorologie*, v. 12, no. 1-2, 1958, 2-5.

The good relations between German and Austrian meteorology and Russian meteorology are part of a tradition which began a century ago, when Alexander von Humboldt gave his valuable and effective support to the establishment of the Central Physical Observatory in St. Petersburg and in so doing laid the foundation for climatological research in Russia. The activity of Kaemtz began in Germany and terminated in Russia. The young Wladimir Köppen went from St. Petersburg to the German Naval Observatory. Our great [A.I.] Voyeykov, a student of Dove, actively contributed to the *Meteorologische Zeitschrift* and other German professional journals. One of his most important works, "Über die atmosphärische Zirkulation," was published in *Petermanns Mitteilungen*. His work, *The Climate of the Earth*, published in Russian in 1884, was translated into German by 1887. The famous names of Sprung, Hann, Assmann, Margules, Hergesell, both Peppplers, Exner, Linke, Süring, Wegener, Weickmann, Schmauss, Stüve, and the old master, Ficker, are remembered by all of us. Many others were also well known to the Russian and Soviet meteorologists.

Soviet colleagues of my generation and I were introduced to the unknown and attractive realm of meteorology through textbooks written by Hann and Süring, Exner, Pernstner, Köppen, Defant, Geiger, and other German authors. On the other hand, our German colleagues were well acquainted not only with Voyeykov, but also with Brounov, [A.V.] Klossovskiy, Sreznevskiy, [B.I.] Kaminskiy, [Ye.S.] Rubinshteyn, Molchanov, Tikhonovskiy, and Kochin. The contributions of Russian meteorologists often appeared in the *Meteorologische Zeitschrift*, an excellent professional journal whose name will endure in the history of meteorology.

Unfortunately, the adverse political events of the 1930's, and more importantly the ill-omened war, destroyed this fruitful cooperation. At present, we are reestablishing these relations. During the years of separation, scientific research in both countries developed independently, although the scientists of both countries set for themselves similar tasks and arrived at similar or complementary results.

Obviously, it is impossible to give in a short lecture even a superficial review of all stages in the development of Soviet meteorology in recent times. We must be content, therefore, with an outline which includes only the development

of Soviet climatology.

Soviet climatologists during the last three to four decades have been confronted with two basic tasks:

- 1) to make a comprehensive description of the climate of their huge country; and
- 2) to lay a better theoretical groundwork for the fundamentals of climatology.

Climatological research in our country, even in old Russia, has always been on a high level. During the last three decades, the basis for climatographic investigations in the Soviet Union underwent considerable expansion. The meteorological network became much denser, even in distant regions such as the Arctic.

A large network of radiosonde stations was developed, which made it possible to begin research on problems of the climatology of the free atmosphere. Recently, certain possibilities have been created for the mechanical processing of observations. These technical preconditions have made it possible to compile an extensive monograph concerning air temperature, air pressure, distribution of wind, and precipitation in the Soviet Union. Ye. S. Rubinshteyn, A. A. Kaminskiy, and O. A. Drozdov collaborated on this monograph.

This work may be regarded as an extensive preparation for the new monumental atlas of climates of the Soviet Union, which is being prepared for publication in the Central Geophysical Observatory. Soviet meteorologists have published a series of works in which the problems of climatological mapping of the Soviet Union and of the whole earth were partially solved. The extensive map series in the *Large Soviet Atlas* and in the second volume of the *Atlas of the Sea* may be listed here. Also compiled were several special atlases, textbooks on climatology and climate descriptions for separate regions of the country, to be used primarily in agricultural meteorology, and several maps showing altitudinal wind distribution. At present, a broader climatological processing of aerological observations is being completed. Numerous observations at our Arctic stations furnished the basic material for various climatological studies of this region.

The book by Fedorov and Baranov, *The Climate of the Plains of the European Soviet Union Represented According to Weather Types*, was published in 1949. In this book, the description of climate was made by means of Fedorov's complex-climatological method. At about the same time, B. P. Alissov's study of the climates of the Soviet Union and his book on the climates of the earth were published. The latter has been translated into German.

Such large climatographic works have naturally stimulated efforts to devise new statistical methods for climatological

purposes or to improve existing methods. As a result, a number of completed works deal with the application of mathematical statistics to climatology, particularly with the reduction of series, and with the interpolation, field structure, and rationalization of grids. Those mainly responsible for work on these problems were Kaminskiy, Kuznetsov, Drozdov, and others. In addition, the probability and frequency of various threshold values of meteorological elements were studied very precisely. The aforementioned Fedorov method of complex climatology is also included here. Equally great attention was given to the development of methods of microclimatic research.

Soviet publications dealing with the subdivision of climatic regions and with the classification of climates were unfortunately not given sufficient coverage in the well-known monograph by Knoch and Schulze.

In the late 1920's, Voznessenskiy classified the climates of the Soviet Union on the basis of Köppen's general classification, but with essential corrections. At the same time, L. S. Berg divided the continent into climatic zones. Berg based his classification on the approximate coincidence of landscape belts with the climatic zones. This subdivision has many points in common with the well-known classification of Köppen, and actually supports the latter against the critics of the formalistic school.

At the end of the 1930's, E. P. Alissov published his genetic classification of climates, based on the mean annual position of climatic fronts. This classification became known in Germany through the translation of Alissov's books.

Recently, Alissov established a detailed climatic classification for our entire country which was published in his new book *The Climates of the Soviet Union*. The characteristics of radiation balance and circulation were used as the basis for the classification. An even more detailed classification is based on the differences of soil and vegetation cover. At approximately the same time, B. T. Selyaninov published another classification of climates of the Soviet Union. As a criterion for the subdivision, the sum total of temperatures during the vegetation period, supplemented by some other characteristics, were used. The subdivision of zones into climatic regions was based on humidity types which were determined according to the well-known Selyaninov humidity factor, in correlation with the annual variation of the precipitation. Finally, in subdividing the regions into climatic provinces, consideration was given to the degree of continentality as it is based on various characteristics, but particularly on the thermal conditions in winter.

Other studies on the continentality of the climate were

also taken into consideration. Four years ago, interest in this problem was again stimulated by a certain work of Ivanov, in which a simple method for establishing the characteristics of the continentality of climate was presented. This method is based on the difference between two annual amplitudes of air temperature, namely, the mean annual temperature fluctuations over the entire parallel of latitude and its annual fluctuations in a given point. The method has the advantage of being simple; moreover it makes it possible to establish a sufficient number of fine details even for small regions. However, it is not completely adequate and tends to be too formalistic to permit the determination of continentality on a worldwide scale.

For this reason, I recently undertook to improve the well-known Gorczyński factor. As a basis I used the so-called "purely oceanic temperature" for each separate latitude, which was calculated according to the amplitude value in the middle of the southern Pacific Ocean. By this method, it is possible to determine the extent of the continental influence upon the climate of the continents, and upon that of the oceans. I have sketched the world map of this continentality. From this I concluded that even a markedly marine climate on a continent is subject to continental influences which more than compensate for the marine influence.

This problem was treated entirely differently by Polosova, a student of Rubinshteyn. She proposes to characterize the continentality separately for summer and for winter, by comparing the temperature anomalies with the extreme anomalies for the entire parallel of latitude.

This work, by the way, is based on the new map of thermal isoanomalies, compiled by Rubinshteyn. By means of this map, Rubinshteyn -- following Meinardus -- has improved the temperature values for latitude parallels, hemispheres, and the whole earth.

Concerning the question of individual elements from which climates are composed, we proceed from the basic assumption that the formation of climate is the result of the three great geophysical processes: 1) the radiation and heat balance of the atmosphere; 2) the general air circulation; and 3) the water circulation between the atmosphere and the earth's surface (hydrological cycle). All three processes are reciprocally and closely connected with one another. However, it may be assumed that the formation of climate is most directly influenced by the atmospheric circulation. On this basis, we can characterize the entire complex of climatogenetic processes simply, distinctly, and unmistakably. In any case, the air circulation, recognized as the most important factor by Voyeykov, Hann, Köppen, and Hettner, takes a preeminent place in research on the formation of climate.

Further, studies were undertaken from the simplest viewpoint of dynamic climatology, as represented, for example, by the "Luftkörperklimatologie" (climatology of air bodies) of Linke. However, these studies went somewhat beyond Linke's approach. During the 1930's and 1940's, several works were published, which appeared to be sufficiently different in respect to methods and the formulation of problems, but which shared the same dynamoclimatologic approach. The first to be mentioned here is the study of the types of synoptic processes and their changes. This study was intended as a basis for the explanation of climatic conditions. Our descriptions of climate have always been based on circulation characteristics as they relate to climatic phenomena. Further, we may mention works whose object has been the study of phenomena resulting from circulation, e.g., drought, dry winds (sukhovei), severe cold and violent winds, sleet, etc.

Several larger works have also been published. These deal with the study of the climatology of circulation processes. We mention here the study of the circulation types for larger spaces of the northern hemisphere, published by Lyr in the 1930's. Then follow the works of Wagenheim, who considered the statistical control of the three main types of circulation as the basis for the determination of types. Finally, Dzerdzeyevskiy classified the circulation types over the entire northern hemisphere through a systematic processing of map materials collected over many years, and investigated the regularities in the changes of those circulation types. I may finally mention my own works on the distribution of climatic fronts and monsoons, as well as the works of Kh. P. Pogosyan, which analyze the position of frontal zones in the free atmosphere.

In the final analysis, almost all of these works are but preliminary studies on the main problem of long-range forecasting. On the other hand, the studies made at the same time by our synoptic climatologists according to the Multanovskiy method, are also of climatological importance.

Alissov, in his genetic classification of climates on the basis of circulation, gave us a simple and clear system which, among other things, agrees perfectly with Flohn's system developed at about the same time. Earlier, Alissov had also developed a method for characterizing climates by weather situations in a given region. He distinguished frontal, convective, transformatory, and other weather situations.

Concerning the study of radiation and heat balance, Soviet climatologists proceeded along the same path as the German climatologists, whose works in this research sector, including the classical study by Baur and Philipps, were well regarded by Soviet specialists. In 1946, under the direction of M. I. Budyko, the climatologists began systematic research

on these problems. Some important results were achieved, which have appeared in several publications. These include the recently published monograph by Budyko, and the *Atlas of the Heat Balance*.

Methods were systematized and elaborated for calculating those components in the heat balance, which are either inaccessible for direct observations, or have not yet been determined by observation. Large series of maps were drawn up, which cover the European part of the Soviet Union, the entire Soviet state, the Northern hemisphere, and finally, the entire earth. These maps contain several new results and corrections, as compared with earlier drafts. Thus, for the first time it was possible to calculate the amount of heat being transported in the atmosphere and in the oceans from lower latitudes to higher latitudes. In any case, it is now possible to see the radiation and heat components represented on the maps, just as other elements of climate are shown. Their use for the analysis of climate formation is to be expected in the near future.

The climatogenetic process of the hydrologic cycle has attracted the attention of climatologists at least since Voyeykov's time. Brückner and Meinardus also dealt with this problem. In the Soviet Union, the problem of water circulation became urgent in connection with large agricultural projects. Two parts of this problem were given particular attention: the question of the role of the internal hydrologic cycle, and the question of moisture indices.

We understand the internal hydrologic cycle to mean the evaporation of precipitation which has fallen in a certain region and its subsequent falling on the same region. Following Brückner's works, this question became very much confused through arbitrary assumptions. In this way, some climatologists started overemphasizing the role of the hydrologic cycle, particularly in such a large territory as ours. Thus, the influence of forests and forest belts upon the climatic conditions of the country has been greatly exaggerated.

Some authors, among them Zinserling, have tried to prove that on the European territory of our country, the precipitation originating from the internal hydrologic cycle can be one and one-half times greater than the precipitation coming from the external hydrologic cycle. They maintain that the afforestation and even the increase in crop yields due to shelterbelts can increase the transpiration, and consequently, the precipitation. An even greater contribution should be expected from the irrigation network in the southern part of the country.

Well-founded calculations of the transporting of water vapor by air currents seriously undermine these optimistic, but fantastic expectations. M. I. Budyko, O. A. Drozdov, and other

authors have found that the share of the precipitation coming from the internal hydrological cycle was for the European territory of the country only 13 to 14% of the total amount of mean annual precipitation. Since this share is so small, all possible irrigation and afforestation measures with the consequent increase in evaporation can contribute very little to an increase in precipitation.

The contribution of the forest to evaporation was also evaluated on the basis of biological data on transpiration. This contribution also proved to be very insignificant.

It is possible, however, that precipitation is increased by ascendant air movements in front of shelterbelts. Even very optimistic estimates, though, do not show that this increase could be of practical importance. The same can be said about irrigation. My calculations showed that irrigation of the entire Caspian lowland and the lower Volga region increases the amount of annual precipitation in this territory by no more than 3 mm.

Concerning the works on the origin of water vapor, drought, and dry winds (sukhovei), we will only note that the studies on the origin of sukhovei by means of air trajectories showed very clearly that these winds develop only rarely in Central Asia. The descending movements here also play a very limited role. The sukhovei are rather a phenomenon of the transformation of air masses on the same territory.

Moisture indices were also found to be of great interest to climatology. A new problem arose in this connection, namely, that of determining the potential evaporation. In this respect, Budyko's works achieved important results concerning the relation between the potential evaporation and the radiation balance. Moreover, we may mention Ivanov's works on the hydrologic cycle for the entire earth and particularly for the tropical zones.

Microclimatic research in the Soviet Union is conducted mainly for agricultural purposes. We have thoroughly explored the influence of shelterbelts on microclimate, particularly through the decrease of the force of wind. Problems of irrigation and drainage, as well as those of land reclamation, have also been analyzed. Several works deal with the physics of the air layer near the ground and especially with the prevailing wind distribution in this layer. Also investigated were the possible effects of the shelterbelt network upon the microclimate, not only upon the precipitation, but also upon the wind in the friction layer. Works on bioclimatology, agricultural meteorology, and soil climate will not be mentioned here.

Paleoclimatology has heretofore not been intensively studied. Nevertheless, there are excellent works in this field of research by the Academician, Berg, on geological climates, historical changes of climate in Central Asia, and the present rise of temperature. The latter problem has been investigated by several scientists including Wiese, Rubinshteyn, and Maksimov. The influence of solar activity on circulation processes and on climate is also being studied extensively in our country. Among others, Eigensson pursued the idea of the possibility of establishing the relationship between geological changes in climate and circulation on the one hand, and fluctuations of solar activity on the other. Similar ideas were simultaneously developed by Willet.

I conclude by expressing the wish that this general outline may serve as a first orientation, and to this extent, be of some value.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph d

SOURCE: Korzun, V. I., V. V. Sidel'nikov, and M. S. Sternzat. Overall automation of hydrometeorological work and the creation of network telemetering stations. *Meteorologiya i gidrologiya*, no. 2, 1961, 13-19.

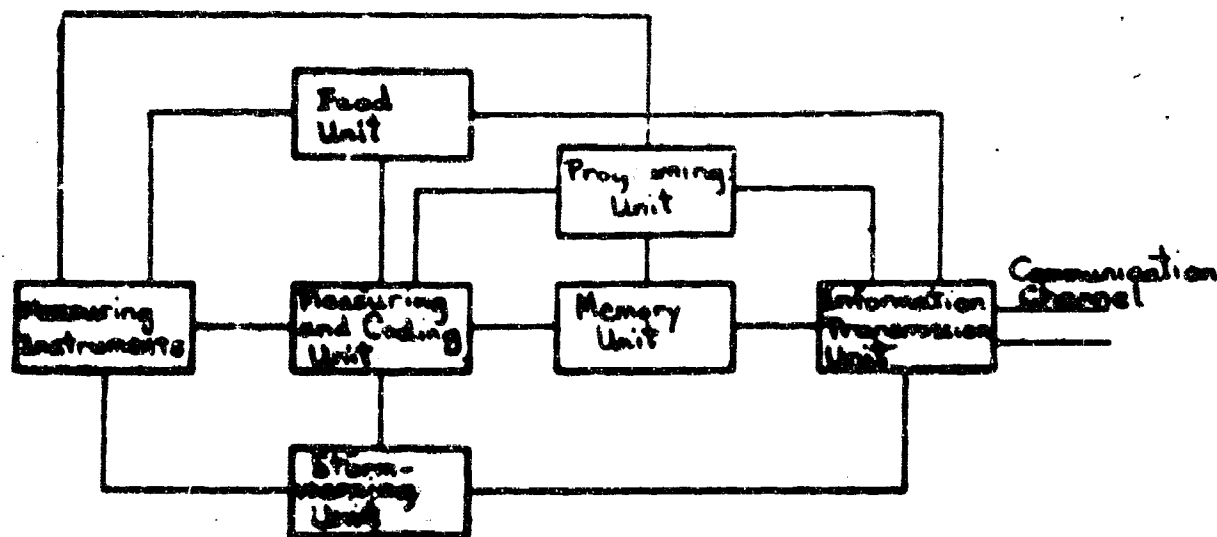
In recent years, the Hydrometeorological Service of the USSR has taken steps in the development and introduction of automation. However, this work has been on a comparatively small scale and has not given full recognition to the importance of the problems of overall automation.

It is now considered of the utmost importance to devise a general scheme for the overall automation of the Hydrometeorological Service and to determine the basic operational and technical requirements to be met by the various components in the system. The scheme should reflect the basic features of the structure and activity of the various organs of the Service which provide forecasting and warning services to the national economy (the weather bureau, aviation meteorological stations, etc.). The various units of the Hydrometeorological Service will undergo substantial changes as regards their composition, location, and techniques. For example, instead of the usual stations and posts, automatic telemetering stations (ATMS) will be used for making observations.

A degree of automation can be introduced into the weather-forecasting service by 1) utilization of electronic computers (universal computers or specially-built computers) in the application of numerical methods, and 2) the automatic compilation of forecasts based on synoptic methods. In this case, it will be necessary to classify and generalize logical relationships inherent in the synoptic method of forecasting and to represent them as algorithms. A special electronic computer can be built for this purpose.

Automation will considerably reduce the number of agencies entrusted with the task of collecting and distributing the results of observations and compiling the forecasts and warnings. It may be assumed that the number of such agencies in the entire country will be reduced to between 10 and 15. A radical solution of the problem of the overall automation of the basic activities of the Hydrometeorological Service does not exclude the need for automating a wide range of operations and processes in specific directions. Thus, for example, the application of automatic and remote-control devices is urgently needed in all types of operations performed at meteorological, aerological, hydrological, and marine hydrometeorological stations and posts. Currently tens of thousands of people are employed in the hydrometeorological network. The automation of observation processes and the processing of results will make it possible not only to reduce the number of personnel, but also to make the observation processes more objective.

In order to automate all operations of the Hydrometeorological Service, it will be necessary to create a network of new automatic telemetering stations. The ATMS must contain units which would assure the performance of all operations of a modern meteorological station (see illustration).



Block diagram of an ATMS

Using the primary measuring instruments (located on a special meteorological platform) and the measuring unit, the ATMS must perform measuring and coding operations and then transmit the information to preset addresses. The station must store the data received (memory unit) in a form suitable for further machine processing and use (punched tapes, punched cards, wire recordings). When some elements reach critical value (high wind velocities, heavy glaze, limited range of visibility, storms), the storm-warning unit, acting on a signal from the corresponding primary measuring instruments, switches in the station, which then transmits the storm warning.

The development of a complex of primary measuring instruments which will meet certain technical requirements is of great importance in the construction of ATMS. Work on such instruments can be divided into two categories: 1) changes to be made in existing instruments by adapting them to the unified technical requirements; and 2) creation of new instruments and new methods of measuring those meteorological elements which are now evaluated visually. The cost of the station is an important factor. Preliminary estimates show that the cost of the ATMS will be determined mainly by the cost of the primary measuring instruments, i.e., of that equipment which must be an integral part of every modern meteorological station. The cost of additional special equipment of the ATMS will amount to about 40 percent of the total cost of equipment.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph d

SOURCES: Indicated below

- 1) Loginov, Ye. The wings of time. Grazhdanskaya aviatsiya, no. 1, Jan 1962, 2-5.

Poor meteorological conditions are responsible for interfering with the regularity of landing operations of scheduled airplanes. It would seem that nothing can be done against the elemental forces of nature. However, more rational utilization of the air fleet could increase considerably the dependability of flights, even under very severe meteorological conditions. Instead of the Tu-104, it is sometimes advisable to dispatch more versatile planes such as the Il-18 or the An-10. However, this is not always done....

Meteorological services for scheduled flights should be improved. The crew should be provided with data on current weather and with forecasts at takeoff time. In this connection, demands will be made on the Main Administration of the Hydrometeorological Service. Airlines should be more amply provided with forecasting charts, and crews should be checked before each flight on their knowledge of weather conditions along the flight route and at the airports at which they are to land.

- 2) Simonyants, V. The day of the present and the future. Grazhdanskaya aviatsiya, no. 1, Jan 1962, 14-16.

Special telephones on the walls of the waiting room at the Vnukovo Airport are connected with the information service. There is also a television set installed in the waiting room. When the button is pressed, a girl working at the information bureau appears on the screen. She will answer questions directed to her. The uses for television in our country are continuously expanding. The chief of the airport and the flight dispatchers use television to observe the entire airport and thus have better control of flight operations....

The dispatcher at the Vnukovo Airport, Yu. S. Folimonov, has invented a device for the rapid automatic computation of meteorological data for each flight to be transmitted to the pilot in the air.

- 3) Ivanov, I. Construction at Aeroflot. Grazhdanskaya aviatsiya, no. 1, Jan 1962, 23-24.

A special planning and scientific research institute, the "Aeroprojekt" has been organized in the Civil Air Fleet. Branches of the "Aeroprojekt" will be established in the near future in the Ukraine, [Soviet] Far East, and [Soviet] Central Asia. This will enable the Civil Air Fleet to solve more rapidly

all problems connected with the planning and designing of construction projects.

- 4) Maksimov, M., M. Shyl'gin, and A. Shmel'kov. The fog retreats. Grazhdanskaya aviatsiya, no. 11, Nov 1961, 19.

Since 1953, experiments with fog modification by means of solid carbon dioxide (dry ice) have been conducted at the Alma-Ata airport. Both ground and airborne installations for dry-ice spraying have been tested. Ground installations seem to be particularly effective for dispersing fog near the ground.

The following conclusions have been reached: 1) In order to increase the regularity of flights, wider use should be made of carbon-dioxide spraying for the dispersion of fog. 2) Carbon-dioxide installations can be used only for the dispersion of intramass clouds and fog at a temperature of -5°C or lower. For this reason, they should be used at airports where the anticyclone type of weather is predominant in winter-time, i.e., in the eastern part of European USSR, in Kazakhstan, and in Siberia. 3) Since in these regions fog near the ground is the greatest obstacle to flight regularity, it is expedient to use economical and simple portable ground equipment for carbon-dioxide spraying.

- 5) Veresotskiy, Ye. The airplane and radar. Grazhdanskaya aviatsiya, no. 9, Sep 1961, 12.

In the Soviet Union, radar flight control is used not only at airport areas, but also along the main air routes through auxiliary radar dispatch stations along the routes. Weather data are transmitted from these stations to the regional dispatcher, who uses them for the evaluation of air conditions and the guiding of air traffic in his zone....

Radar also makes it possible to determine frontal storms. If it is impossible to fly above these storms, then the decision is made to cancel the flight. The detection of storm fronts is of great importance, insuring safe and regular flights. Therefore, in addition to ground radar installations, radar sets are installed aboard aircraft, thus enabling the crews to bypass the storm clouds. This is particularly important at night, when the naked eye cannot discern the character of the cloudiness into which the plane is heading. The coordinated action of ground and airborne radar systems contributes to safety in any kind of weather.

- 6) Brodskiy, A. The pilot receives a weather chart. Grazhdanskaya aviatsiya, no. 7, Jul 1961, 26-27.

What constitutes a comprehensive meteorological service to aviation? In the first place, there is the preflight briefing

of the crew. We have preliminary and final briefings, the latter an hour or thirty minutes before takeoff. During the session, synoptic meteorologists brief all crew members on the actual and expected weather conditions along the flight route. In addition to the weather-forecasting chart given to the plane crew before takeoff, meteorological and aerological maps, graphic representations of the vertical cross sections of the atmosphere along the flight route, and other special materials are explained to the pilots and crew members.

The meteorological service to aviation also includes the servicing of planes in the air through ground stations (airport dispatcher offices, regional dispatcher stations, and meteorological stations). Here too, progress has been made through the application of new techniques which make it possible to use the very latest aerosynoptic charts for informing plane crews about weather conditions. Aviation forecasting charts are compiled by using the aerosynoptic data received by the meteorological station, the data of aircraft sounding, and the reports of crews concerning weather conditions along the route. The charts may be compiled for six, eight, or more hours, depending on the duration of the flight and the complexity of aerosynoptic processes occurring on that day.

7) Loginov, Ye. Toward high-quality meteorological services for flights. *Grazhdanskaya aviatsiya*, no. 11, Nov 1960, 10-11.

The data in a weather bulletin must meet certain specific requirements of the flight mission, provide a basis for correct decisions regarding takeoffs, and lead to the selection of an appropriate flight plan which would be in accordance with the traffic and would make it possible to surmount the complex weather conditions on the flight route.

Specifically, the weather-bulletin data should furnish information on the following: a) pressure characteristics; b) weather forecasts along the route which satisfy the above-mentioned requirements; c) weather forecasts for the landing point (with the characteristics of the meteorological conditions at the auxiliary airport and takeoff airport); d) wind conditions by altitude.

8) Sheynin, M., and A. Yakovlev. Radar sounding of the atmosphere. *Grazhdanskaya aviatsiya*, no. 1, Jan 1960, 14.

The use of radar reflectors is recommended as a means for determining the velocity and direction of wind and the character of vertical air currents. It has been experimentally proved that the application of radar reflectors makes it possible to extend to the free atmosphere the terrestrial radar method for recording the mean square velocity of motions in the clouds.

- 9) Loginov, Ye. Early fulfillment of the Seven-Year Plan!
Grazhdanskaya aviatsiya, no. 7, Jul 1960, 1-2.

The crews of the Civil Air Fleet are taking aerial photographs, are taking an active part in scientific research work on studies of the Arctic and Antarctic, and are rendering services to fishermen and hunters and to numerous geological expeditions prospecting for minerals. The extensive use of aviation in geological surveying has contributed to the discovery of large deposits of nonferrous metals in the Krasnoyarskiy kray, gold in Magadanskaya oblast', gold and diamonds in the Yakutskaya ASSR, and oil and natural gas in the Tyumenskaya oblast'....

The Civil Air Fleet is rendering assistance to other Socialist countries and underdeveloped countries in the field of civil aviation by helping in the training of specialists, supplying advice and making available technical aviation publications and other training aids.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph 4

SOURCE: Mirtov, B.A. Gazovyy sostav atmosfery Zemli i metody yego analiza (Gaseous composition of the earth's atmosphere and methods for its analysis). Moskva, Izd-vo AN SSSR, 1961. 261 p.

ABSTRACTS:

Micrometeorology (Stratospheric balloons)
[pp. 51-54]

The study of the upper layers of the atmosphere began in the USSR with the launching of the stratospheric balloon "CCCP" in September 1933. The balloon, which rose to an altitude of 19 km, carried an air-sampling flask designed by A.I. Shal'nikov and M.I. Gol'tsman. The flask was enclosed in a metal container and attached to the outside of the gondola to avoid contamination by gases escaping from the balloon. The flask's opening and closing mechanism was controlled electrically through wires leading into the interior of the gondola. The air-sampling vessel (see illustration) consisted of a 1-liter glass cylinder 1 with two arms -- arm 2 for letting the outside air in, and arm 7 for attaching the cylinder to the air-analysis equipment.

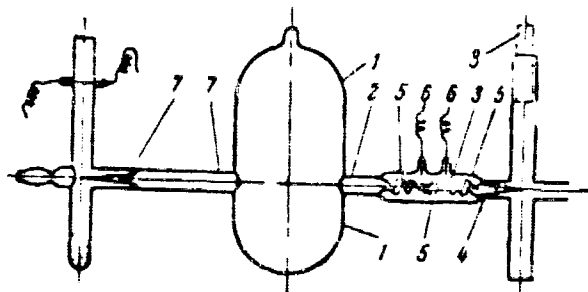


Diagram of the Shal'nikov-Gol'tsman flask

1 - cylinder; 2 - air intake arm; 3 - capillary;
4 - capillary tip; 5 - sleeve; 6 - platinum heater;
7 - cylinder arm for attaching cylinder to installation; 8 - weight.

Before ascent, the cylinder was evacuated to 10^{-5} mm Hg and sealed. At the terminal altitude, the locking of a special relay released weight 8, which in falling opened a third arm 4, allowing the

) surrounding air to enter the evacuated flask. Within a certain period of time, platinum heater 6 melted capillary 3; air released from sleeve 5 then compressed the heated capillary, thoroughly sealing the vessel. To prevent the hydrogen in the balloon from entering the cylinder, sampling was effected during gradual descent. Separate analyses of the samples made by A.V. Mosvin and A.A. Cherepennikov, produced identical results: pressure in cylinder, 47.5 ± 0.2 mm Hg ($T = -55^{\circ}\text{C}$); hydrogen, none observed; content of O_2 , 20.95% at altitude of 18,000 m; content of N_2 and inert gases, normal (79.05%). The results showed that the composition of the air at an altitude of about 20 km is the same as that in the surface layer.

In 1934, the stratospheric balloon "Osoaviakhim" rose to an altitude of 22,000 m but was lost with all hands aboard. The air-sampling flasks were situated inside the gondola and probed the outside air by means of pipes which were opened and closed electrically from within the gondola cabin.

Meteorological Sensing Equipment [p. 78]

A recent Soviet single-stage geophysical rocket reached an altitude of 475 km carrying a payload of 1 ton. This great payload capacity enables the rocket to carry special automatic containers with a variety of instruments, including radio-frequency mass spectrometers and cylinders for storing air samples. In sampling, the containers are ejected to the side of the rockets; this makes it possible to obtain purer samples than if the containers were to remain fixed to the rocket. Meteorological rockets are also used in investigations at lesser altitudes. Measuring equipment is carried in the head of the rocket, which is recovered by parachute.

Instrumentation [p. 99]

In discussing high-altitude air-sampling techniques conducted with the aid of rockets, Mirtov suggests that the difficulties encountered by American scientists in designing suitable opening and closing mechanisms for rocket-borne sample containers could be easily solved. The end of the metallic inlet duct could be sealed by a thin-walled glass tube and the tube broken at the required moment to provide an opening into the vessel.

Meteorology (Radio-Frequency Mass Spectrometer for the Analysis of
The Neutral Components of the Atmosphere)
[pp. 166-172]

In the summer of 1959 a Bennett-type radio-frequency mass spectrometer, designed by the State Specialized Design Office, Academy of Sciences USSR, was propelled to an altitude of 200 km in the middle latitudes of the USSR to study the neutral components of the atmosphere. The new instrument, based on the V.G. Istomin mass spectrometer, was specially designed to determine the presence and extent of hydrogen and helium in the upper atmosphere.

In contrast to the instrumentation of the U.S. Aerobee rockets, the mass spectrometer was placed in a self-contained capsule. The compartment housing the mass spectrometer, the telemeter, and the oscillograph was hermetically sealed rather than open-worked. The analyzer tube of the mass spectrometer probed the atmosphere through the walls of the compartment, and was hermetically sealed to the capsule facing by means of a special flange. To avoid the effects of gas-emitting surfaces at great heights, the analyzer tube with its mouth located below the capsule walls was placed in a wide glass vessel in such a way that the walls of the capsule were out of the field of vision of the spectrometer. Radio transmitter antennas were attached to the outside walls of the compartment.

On the rocket's upward trajectory, the capsule containing the mass spectrometer is ejected from the rocket, and continues independently on its own trajectory. At a given altitude, the mass spectrometer tube is unsealed, and analysis of the surrounding air is initiated.

A.A. Pakhunkov, who processed the data obtained, reports the following results:

The mass spectrometer recorded dozens of types of ions identified with H_1 , H_2 , OH , H_2O , N_1 , O_1 , N_2 , O_2 , Ar , and CO_2 , which formed in the ion source of the spectrometer. The characteristics of the intensity peaks recorded on the spectrograms made it possible to separate the gases into two basic types: the water group of gases and their derivatives -- H_2O , OH , H_1 , H_2 -- relating to the contaminating gases brought by the capsule and rocket, and the atmospheric group -- O_1 , N_1 , O_2 , N_2 , Ar , CO_2 .

The rotation of the capsule induced by its ejection from the rocket made precise separation of the two groups of gases possible. Because of the rotation, the axis of the mass spectrometer tube altered its direction in relation to the capsule's forward velocity vector. The total pressure in the tube also varied: it was greatest when the angle between the axis of the tube and the forward velocity vector of the capsule was at its minimum and smallest when the angle was greater than 90° ; i.e., when the mouth of the

mass spectrometer tube fell within the area of molecular shadow which formed behind the capsule (Fig. 1). Peak intensity, induced by and related to the "cloud" of contaminating gases released by the container, was not subject to such variations, because the gases created a constant pressure in the instrument independent of the capsule's orientation (Fig. 2).

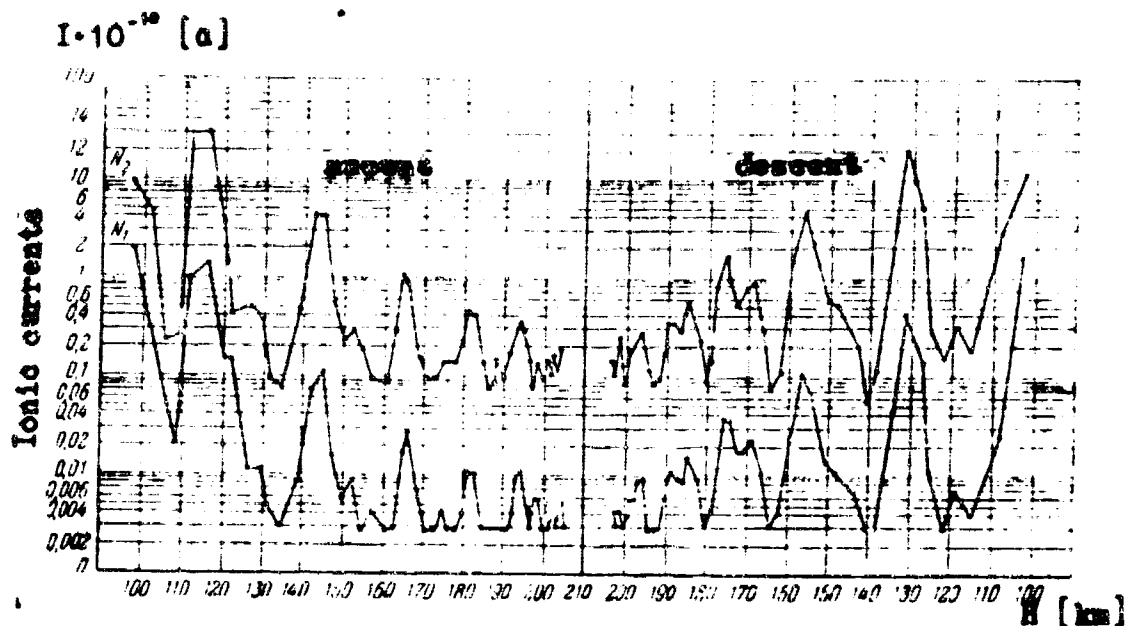


Fig. 1. Amplitude variations (pulsations) of ion currents of molecular and atomic nitrogen related to the rotation of the capsule

Analysis of the variations in the intensity of ion peaks in the water group showed that the quantity of these gases declines slowly and monotonously throughout the entire flight; this finding confirmed their desorptional nature. Assuming that the law of desorption of water is satisfactorily expressed by the exponential function

$$I = I_0 e^{-\frac{t}{\tau}}$$

satisfactory agreement between theoretical and experimental values was obtained by normalizing this function for water. (I_0 is the ionic current of H_2O at time $t = 0$. On Fig. 2 it amounts to $6 \cdot 10^{-11}$ a. Term τ is the index of "fall", 316 sec.)

A discrepancy between experimental and theoretical values occurred only in the case of H and H_2 . In the case of molecular hydrogen, the discrepancy was explained by the presence of atmospheric hydrogen, or more probably by hydrogen separated from the

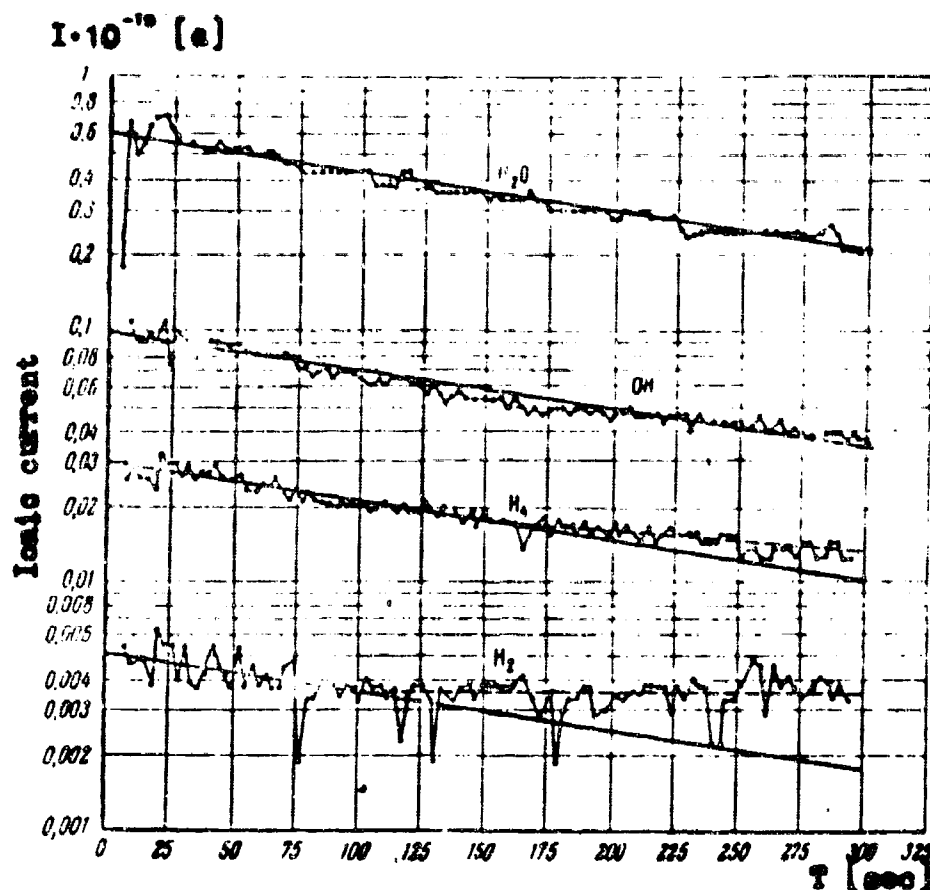


Fig. 2. Aperiodic oscillations of ion currents in gases of the water group

inside surface of the analyzer tube which was initially filled with a mixture of H_2 , He, Ne, and Ar to calibrate the instrument before and during flight. The excess hydrogen, indicated by the ionic current, was estimated at $3 \cdot 10^{-13}$ to $2 \cdot 10^{-12}$ a. Pokhunkov concludes that at 100 to 200 km the amount of neutral hydrogen should therefore not exceed $1 \cdot 10^8$ particles per cubic centimeter, which is just within the limit of the sensitivity of the spectrometer.

The rotation of the capsule, which facilitated discrimination between atmospheric and "parasitic" gases, impeded the processing of atmospheric gas spectrograms. Because the data being processed could not be corrected "for orientation", further computations were based on points situated only within the maxima of "primary" curves (Fig. 1). This greatly reduced the amount of the material which could be used for processing.

In "secondary" processing only selected "primary" data on ion peak intensities of two random gases were compared. An analysis of the ratio of N_1 to N_2 ion peak intensities revealed no perceptible quantities of atomic nitrogen at an altitude of 100 to 200 km.

Similar curves plotted for atomic and molecular oxygen provided only a qualitative spread because oxygen may undergo basic transformations in entering and leaving the spectrometer analyzer. Nevertheless, the experiments described provided a clear picture of the general distribution of atomic oxygen by altitude. It was found that the increase of atomic over molecular oxygen began at an altitude of 100 km and continued rising to 200 km, the lowest and highest levels at which measurements could be made.

Analysis of the change in the ratio between Ar and N₂ is of considerable interest in determining the gravitational separation of gases. Pokhunkov found that gravitational separation occurs at about 100 km, though the limited number of points at which measurements were made prevented him from obtaining a quantitative evaluation. In the experiments described only very small amounts ($> 10^8$ atoms/cm³) of hydrogen and helium were detected.

Gravitational Separation of Argon and Nitrogen in the Atmosphere [p.174]

Mirtov believes that the accuracy of the results obtained in the U.S. investigation of the gravitational separation of atmospheric nitrogen and argon of 12 Feb 1953 with the Aerobee NRL-13 is questionable. The cap over the inlet to the mass spectrometer played a negative role, proving a natural trap which enriched the atmosphere around the inlet with argon.

The surrounding atmosphere, composed of a mixture of different gases, reached the inlet of the instrument through slots in the cap. If the free paths of the molecules were not large, this gaseous mixture would reach the mass spectrometer with its composition undistorted. The picture would change drastically, however, if the free paths of the molecules should be comparable to the mean distance between the inside walls of the protective cone. The molecules should be comparable to the mean distance between the inside walls of the protective cone. The molecules entering through the slots would then be subjected to numerous collisions with the walls of the housing before leaving the cavity. "Fast" nitrogen would leave the trap in larger quantities than "slow" heavy argon, creating a false picture of the gravitational separation of these gases.

This hypothesis is confirmed by analogous studies conducted by Soviet scientists in the middle latitudes of the European USSR, in which the separation of argon and nitrogen at altitudes of 110 to 115 km was recorded.

Meteorology (Soviet Investigations of the Ionic Composition of the Atmosphere)
[pp. 182-187]

The first radio-frequency mass spectrometer used in the USSR for upper atmospheric research was developed in 1957 by V.G. Istomin. This spectrometer differed from Townsend's in that its analyzer and ion sources were equipped with "single-row" grids made from parallel wires 18 microns thick stretched at 0.5-mm intervals over a kovar ring. These "grids" increase the resolving power of the spectrometer tube and facilitate its calibration. Prior to final sealing, the tube is filled with an Ar + N₂ mixture and sealed off when the mixture reaches a pressure of approximately $3 \cdot 10^{-8}$ mm Hg. This refinement eliminates intermediary adjustment and allows calibration at any time prior to launching.

Istomin's mass spectrometer has a mass range of 6 to 50 atomic units, its measurement time for the entire range is 1.7 sec, and its resolution in the region of mass number $M = 28$ is equal to

$$R = \frac{M}{\Delta M} = 28,$$

where ΔM is the width of the peak at its base, expressed in atomic units of mass. The amplifier's exit resistance is 10^{10} ohms.

Geophysical rocket launched 9 Sep 1957. On the evening of 9 Sep 1957, a geophysical rocket carrying a capsule containing measuring instruments was launched to an altitude of 206 km from a spot in the middle latitudes of the European USSR. The capsule carried a radio-frequency mass spectrometer which was designed to measure the mass spectra of positive ions. The capsule was hermetically sealed and equipped with a radiotelemetering device which transmitted the data obtained to receiver stations on the ground. The operating orifice of the analyzer tube of the spectrometer was situated in the side of the capsule to remove reflecting (gas-emitting) surfaces from the instrument's field of vision. The rocket quickly left the region of the earth's shadow, and measurements were conducted in an area illuminated by the direct rays of the sun.

In all, 170 spectra were obtained -- the first at an altitude of 105 km on the ascending trajectory, the last at 120 km during descent. Three ions with mass number 16, 30, and 32 (O^+ and O_2^+) were observed. At a height of 105 to 190 km, O^+ and O_2^+ ions were present in amounts no greater than 20% of the amount of the basic NO^+ ion, which predominated at all altitudes studied (105 to 206 km). Ions were recorded at 190 to 206 km, and it was noted that their

number increased with height. Since the spectrograms obtained show no systematic displacement of ion peaks, it may be assumed that the charge in the container remained constantly within ± 2 v. The spectrometer worked smoothly throughout the operation, and a post-recovery check showed that it could be used for further work.

Geophysical rockets launched 2 Aug and 13 Aug 1958. Two geophysical rockets were launched in 1958 -- one on 2 Aug, the other on 13 Aug -- over the middle latitudes of the European USSR. In both rockets, the same type mass spectrometer was used as that on 9 Sep 1957. The capsules ascended to an altitude of about 200 km, and large quantities of mass spectra of positive ions were obtained. Recording began at an altitude of 100 km and continued to maximum ascent.

In general, the cross sections obtained of the ionosphere agreed with those obtained earlier both in the USSR and in other countries. The basic ion at lower levels was found to be the ion of nitrogen oxide NO^+ . Above 150 to 160 km, ions of atomic oxygen O^+ began to appear, their concentration rising quickly with height. The ion of molecular oxygen, whose concentration tends to decline in daytime, was found to be present in considerable quantities, predominantly at lower levels (100 to 150 km).

Geophysical rocket launched 22 Jul 1959. The 22 Jul 1959 geophysical rocket launched over the middle latitudes of the European USSR carried the new mass spectrometer [see p. 3] designed for analysis of the lighter gases. The spectrometer operated successfully, reaching a height of approximately 200 km and recording a large number of mass spectra of positive ions. Of considerable significance were the data obtained on hydrogen and helium. The mass spectrometer failed to detect any hydrogen and helium ions below 200 km, and their apparent absence led Istomin to conclude that the concentration of hydrogen or helium ions in that region of the ionosphere could not exceed 10^3 particles per cubic centimeter, a value coinciding with U.S. findings.

Conclusion. The lower ionospheric layers consist basically of positive ions with a mass of 30 (nitrogen oxide NO^+). This condition is disturbed only toward midday, when considerable quantities of molecular oxygen ions appear at an altitude of 100 to 120 km. At 140 to 150 km, the O^+ ion appears and begins to predominate over the NO^+ and O_2^+ ions. It rises rapidly in concentration with height and becomes predominant above 200 km.

It is difficult to make any definitive statements about the distribution at these altitudes of the lesser ionospheric components such as N_2^+ and H_2O^+ . The presence in the upper layers of the ionosphere of the ion with a mass of 18 (presumably an ion of water) also presents particular difficulties, as does the geophysical basis for the large quantities (1%) of the ions of water at such great heights as 150 km and higher. The absence of hydrogen, helium, and hydroxyl ions in the ionic spectra obtained points to the absence of significant amounts of hydrogen between the altitudes of 100 and 250 km. The presence of the nitrogen ion N_2O^- in the ionosphere was detected each time a spectrometer was sent up, and small quantities of this ion, as well as small quantities of other negative ions in the earth's atmosphere, appear to be quite probable. However, the presence of N_2O^- may be due to rocket fuel combustion.

Stations: Ozone Studies [p. 229]

The USSR has established a network of stations for the systematic study of variations in the atmospheric content of ozone. The stations were set up at Voyeykovo near Leningrad, Abastumani, Terskol at the foot of Mt. El'brus, Alma-Ata, Vladivostok, and Dikson Island. One of the main objectives is the study of the earth's general atmospheric circulation and its relation to weather. Because ozone is retained in the lower layers of the atmosphere for as long as several months, it can be used as an indicator of the transfer of air masses.

Meteorological Equipment [p. 229]

The USSR has developed an improved three-channel photoelectric ozonometer, the O~~3~~OT-3, equipped with three ultraviolet light filters. It determines the amount and vertical distribution of ozone in the atmosphere by measuring the ultraviolet radiation of the sun. Another device, a double-quartz monochromator with a photoelectric receiver for ultraviolet radiation has been adapted by the Moscow State University for the same purpose.

Micrometeorology (Aerosols)

[p. 230]

About two thirds of the aerosols are concentrated in the first two km above ground. Aerosols may account for as much as one third of the absorption of light, usually ascribed entirely to the effect of ozone. The optical density of aerosols increases toward midday and before the onset of cloudiness, which may lead to the erroneous conclusion that there is a daily variation in the ozone content of the air. On the basis of a number of experiments, Mirtov concludes that the content of ozone in the atmosphere varies very little from one day to another. G.P. Gushchin found that the effective radius of aerosol particles is ~ 0.11 to 0.26 microns and their total number $\sim 10^7/\text{cm}^3$.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph *ka*

SOURCE : Gandin, L. S. O printsipakh ratsional'nogo razmeshcheniya seti meteorologicheskikh stantsiy (Principles of an effective arrangement of the network of meteorological stations). IN: Leningrad. Glavnaya geofizicheskaya observatoriya imeni A. I. Voyeykova. Trudy, no. 111, 1961, 81-98.

The correct approach to the problem of setting up a highly productive network of stations should be based on economic considerations. If stations are too far apart, their number must be increased if more accurate weather forecasting is to be expected. The benefits gained by the national economy through better weather forecasting will more than justify the cost of equipment and maintenance of stations. If, on the other hand, stations are too close together, their number may be reduced. This will result in substantial savings without adversely affecting the economic life of the country. In principle, therefore, an "optimum" density of the meteorological network can be established.

Numerous papers have been written on the subject. In 1936, O. A. Drozdov suggested a method based on the computation of the mean quadratic error of the linear interpolation of meteorological elements on the center of the segment connecting two stations. A later work by Drozdov and A. A. Shepelevskiy presented an indirect and easy method for arriving at the interpolation error. They introduced into the computations the so-called extrapolation error, which represents the mean square difference of deviations from normal of the investigated meteorological element at two points as a function of the distance between them. The maximum allowable distance between the observation points was determined by following these steps: 1) finding the structural function of the investigated element; 2) eliminating the effect of the observation errors; 3) determining the linear interpolation error, E_1 , or E_2 , as a function of the distance l between the points according to either of the following two formulas:

$$E_1 = bf\left(\frac{l}{2}\right) - \frac{1}{4} bf(l), E_2 = bf\left(\frac{l}{\sqrt{3}}\right) - \frac{1}{3} bf(l);$$

and 4) determining the value of the distance l by adjusting the permissible error of the element f to the error of interpolation.

The main requirement of the method advanced by Drozdov and Shepelevskiy is that the maximum permissible distance between the points should be determined from the evaluation of the interpolation errors. The next step would be to change from the

estimation of the errors of linear interpolation to the computation of the errors of the optimum interpolation, whereby the observation errors would also be taken into account. In the author's opinion, this would greatly improve the Drozdov-Shepelevskiy method without changing in any way its basic principles.

Before the new technique can be conceived in plain terms, additional research will be needed on such aspects as the "region of influence" used in interpolation, the effect of deviations of the autocorrelation moment, and the effect of the incidental error on the accuracy of interpolation.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph 2 *A.2*

SOURCE: Bozhevikov, N. S. Interdepartmental conference on problems of the transparency of the atmosphere and visibility. *Meteorologiya i gidrologiya*, no. 5, 1960, 62-63.

On the initiative of the Main Geophysical Observatory, an interdepartmental conference was convened in January 1960 in Leningrad to discuss problems connected with atmospheric transparency and visibility. Participating were representatives of 42 institutions and scientific research institutes. Twenty papers, dealing mainly with the problems of meteorological services to aviation, were read and discussed.

The report of N. V. Petrenko outlined the requirements of aviation meteorologists in determining the range of visibility. With present-day flight velocities and traffic density, it is difficult to provide meteorological data to aviation without an exact and operative method for determining visibility and cloud altitudes by means of modern recording instruments. A. V. Gavrilov dealt with the problem of determining landing visibility. On the basis of the theory of photometric contrasts, Gavrilov devised methods for determining the range of visibility of a runway in daylight. A new recording photometer for measuring the transparency of the atmosphere is described in the report of V. I. Goryshin. N. S. Bozhevikov presented information on a new instrument which makes it possible to measure and record, every 30 seconds, the altitude of clouds and the pulsation of their lower level in daytime and nighttime. Tests made with this instrument provided interesting data on the fluctuation of the lower edge of clouds in time and space and revealed a certain relationship between the altitude of clouds and visibility.

Other reports were concerned with the following: evaluation of visibility by sight (I. N. Nechayev); methods and instruments for the equipment of basic meteorological stations; new principle in the determination of the transparency of air (V. A. Gavrilov); design and theory of the M-53 polarizing indicator of visibility (L. L. Dashkevich); nephelometric method of measuring the meteorological range of visibility (G. Ya. Bashilov) (this report includes abundant experimental material demonstrating the possibilities of nephelometric measurements); accuracy of different methods for measuring the meteorological range of visibility (I. A. Savikovskiy); synoptic processes leading to poorer visibility because of the formation of low clouds; effect of precipitation on the transparency of the atmosphere (Ye. A. Polyakova) (this report includes experimental evidence that the coefficient of transparency in the case of snowfall is approximately one order lower than in the case of rainfall).

new data on modern equipment of runway illumination (Yu. V. Frid); problems of the visibility of objects illuminated by searchlight and a method for calculating the brightness of dispersed light from searchlights (G. V. Rozenberg); and some problems of physiological optics and analysis of vision functions (V. B. Baranovskiy).

The conference emphasized the great importance of measurements of atmospheric transparency and of the lower edge of clouds for meteorological services to aviation. It called for the improvement of methods of visual observation and the further development of recording instruments. Such urgent problems as takeoff and slant visibility, transparency in horizontal and oblique directions at a low cloud level, and problems connected with the determination and forecasting of visibility were singled out for special attention. The conference resolved to ask the Main Administration of the Hydrometeorological Service to organize a coordinating commission on visibility problems.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph 2

SOURCE: Kogan-Beletskiy, G. I. Evaluation of conditions for high-altitude
flights. Meteorologiya i gidrologiya, no. 4, 1960, 10-16.

As flights in the upper troposphere and lower stratosphere become more frequent, the importance of meteorological data for navigational calculations increases. The meteorological service to aviation has the duty not only of providing weather information and forecasting, but also of seeing that effective use is made of the data provided.

Usually, the flight-performance characteristics of an aircraft are stated as they relate to conditions of the Standard Atmosphere (SA). Actually, these characteristics can vary considerably, because of considerable discrepancies between actual temperature, pressure, and air density and their standard values. Depending upon atmospheric conditions, changes occur mainly in fuel consumption rate, propulsive force of the motors, vertical velocity, and ceiling. High ceiling and considerable velocity enable modern aircraft to make flights in the lower stratosphere, i.e., above the clouds which usually form in the troposphere and above the zones of intensive turbulence and icing.

The meteorological conditions of flight influence economic efficiency and flight safety. Both of these factors must be considered when making recommendations and giving directives for avoiding dangerous meteorological phenomena along the flight route. In every case, the correct solution to this problem can be found only after a thorough evaluation of the effect of meteorological factors upon the flight-performance characteristics, particularly upon the ceiling.

For the majority of modern airplanes, the ceiling is above the lower fringe of the stratosphere of the SA (11 km). For these altitudes, the barometric altitude of the ceiling, taking into account the actual temperature of the air, can be computed according to the formula

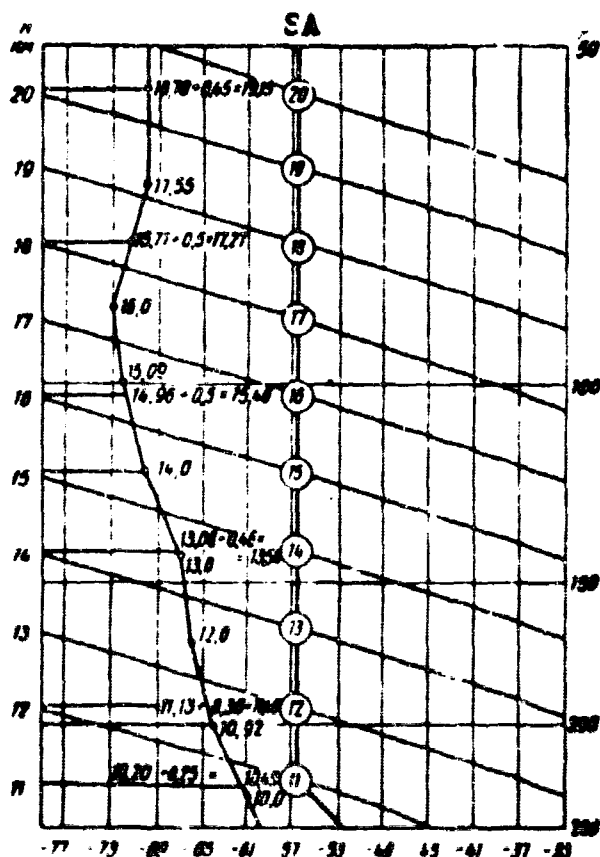
$$P_{pf} = \frac{1}{1 + h_t \frac{\delta T}{T_{st}}} P_{ps} \quad (1)$$

where P_{pf} is the atmospheric pressure at the ceiling under the conditions of the actual atmosphere; P_{ps} is the atmospheric pressure at the ceiling under SA conditions; δT is the discrepancy between actual temperature and the temperature under SA conditions; T_{st} is the temperature in the SA stratosphere (216.5°K); and h_t is the special index expressing the percentage of the change in engine thrust when the temperature diverges from SA temperature by one degree.

An evaluation of the influence of meteorological factors upon the ceiling should not be limited solely to a consideration of the discrepancy between the air temperature and the SA temperature. Such a limitation would make it possible to calculate only the barometric altitude of the ceiling. For evaluating the meteorological conditions of flight and for selecting the best possible flight route

and profile, it is necessary to know the absolute altitude (above sea level) of the ceiling. Synoptic meteorology and aerology indicate the distribution of meteorological elements by altitude with reference to sea level. Therefore, in addition to barometric altitude, absolute altitude must also be known in order to evaluate meteorological conditions and their effect upon flight. Once the elevation above sea level of the flight area is known, it is easy to compute the true altitude from the absolute altitude.

An aerological diagram can be plotted for calculating the barometric and absolute altitude of the ceiling. On the basis of the formula (1), limits were calculated within which the barometric altitude of the ceiling changes in dependence upon different values of air-temperature deviation from the temperature under SA conditions. The index h_t was taken as equal to - 1.5. Usually, the value h_t may change within the limits from - 1.0 to - 3.5, depending on the type of engine, its operational conditions, altitude, and the M number. The obtained values of the changes of aircraft ceiling, depending upon the discrepancy between actual air temperature and temperature under SA conditions, are plotted for altitudes from 11 to 20 km on the aerological diagram. (See figure.)



Example of computing the aircraft ceiling and absolute altitude for scaling on an aerological diagram

The figure shows an example of calculations of barometric and absolute altitudes of the ceiling at various levels, taking into account the actual distribution of pressure and temperature by altitude. The calculation of ceiling for actual conditions of the atmosphere can be done without difficulty. In long-distance flights, the calculation of the ceiling is made according to the data of soundings over several points. Baric topographic charts may also be used for this purpose.

Experiments have shown that considerable fluctuations of the ceiling can be expected. Therefore, for economic efficiency and flight safety, correct evaluations of meteorological conditions along the flight route are of great importance. These evaluations help in the selection of flight plans to avoid the most dangerous meteorological phenomena, especially the zone of turbulence and thunderstorm activity.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph 2 *u*

SOURCE : Mirtov, B. A. Rockets, satellites, and the investigation of the upper atmosphere. Priroda, no. 10, Oct 1961, 23-31.

In the Soviet Union, intensive research on the upper layers of the atmosphere is being carried out by means of powerful geophysical rockets. Along with their indisputable advantages, these research rockets also have certain disadvantages, which are particularly evident at altitudes above 100 km. One such disadvantage is contamination of the surrounding space with gases emanating from rocket surfaces and inner compartments.

The USSR was the first to use an automatic container ejected from a rocket to study structural parameters of high layers of the atmosphere at points distant from the rocket itself. Several versions of this container are now available to Soviet researchers. One is stabilized in space after ejection from the rocket. This type is necessary, for example, in the study of solar radiation. Other versions descend to the earth by parachute, bringing back the sensitive instruments (Fig. 1).

These containers, now widely used in the USSR for atmospheric research, make possible the more reliable measurement of such structural parameters as neutral and ionic composition of the atmosphere and its density, temperature, and pressure. They are also used in the study of ultraviolet and X-ray regions of the solar spectrum, corpuscular radiation, solid interplanetary matter (meteorites and micrometeorites), and airglow.

The central problem in the investigation of the high layers of the atmosphere is the study of their composition. Without knowledge of the composition, it would be impossible to reliably determine other parameters, such as density, temperature, radiation phenomena, and chemical and photochemical reactions. Air sampling by early research rockets (1949-1950) aided in determining the lower limit of the gravitational separation of gases. It

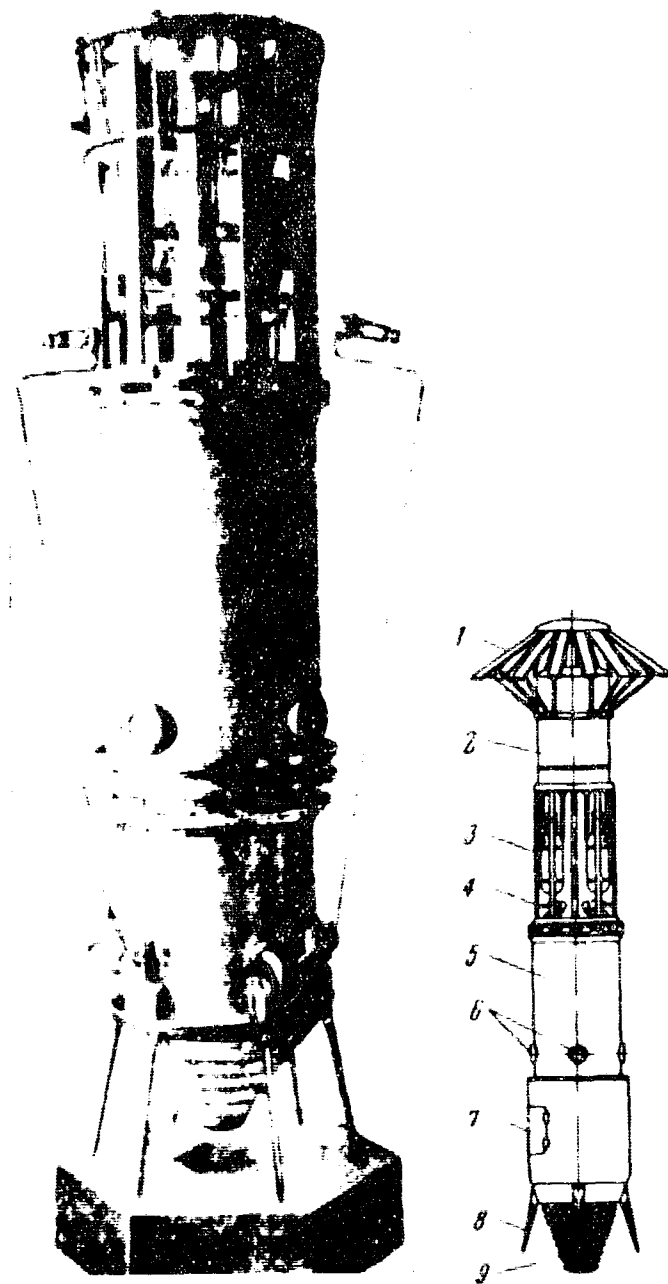


Fig. 1. Retrievable automatic container

Left -- general view of the container (without parachute chamber). Right -- complete diagram of the container. 1 - braking flaps; 2 - parachute chamber; 3 - balloon for taking air samples; 4 - pressure gages; 5 - instrument chamber; 6 - cameras; 7 - pickups of micrometeorite collisions; 8 - shock-absorbing spikes; 9 - corrugated (shock-absorbing) attachment.

was experimentally established that in the upper atmosphere (~ 100 km) the ratio of the mass of nitrogen to the mass of argon increases, as compared with the surface air layer. However, no such separation of oxygen and nitrogen was encountered.

The search for new ways and means to study the atmosphere above 100 km has led to the use of the radio-frequency mass spectrometer (Fig. 2), which can measure not only the amount of stable neutral components of the atmosphere, but also its ionized component (the ionosphere). Investigations of the composition of

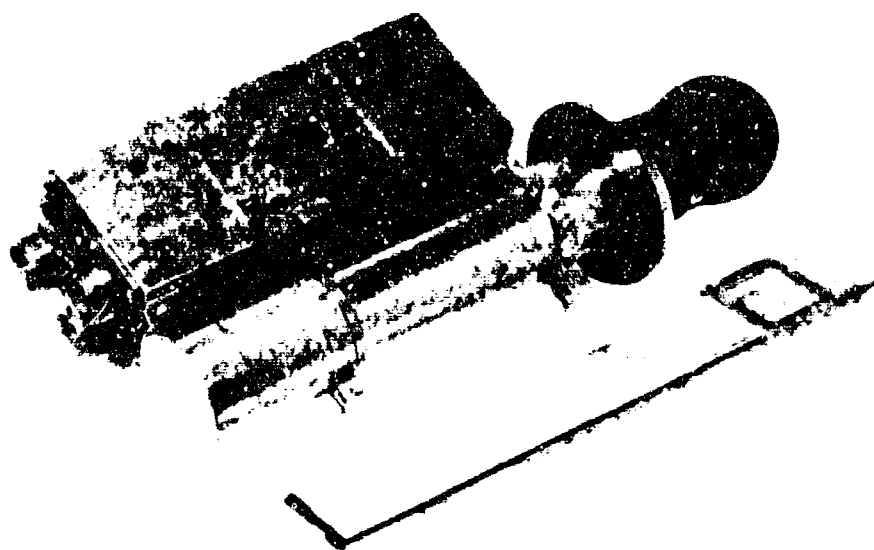


Fig. 2. Improved radio-frequency mass spectrometer

the atmosphere with the radio-frequency mass spectrometer were initiated in the Soviet Union by V. G. Istomin in 1957. Since then, a great amount of experimental data on the ionic composition of the upper layers of the atmosphere has accumulated. In comparing the results of Soviet investigations of the ionosphere with the results of American studies made at Churchill, Canada, one notes good agreement of the characteristic features of the ionosphere, despite the fact that the Soviet investigations were carried out at middle latitudes, while the American studies were done at high latitudes.

The investigation of the light gases, hydrogen and helium, is of primary importance in the study of high layers of the atmosphere. Evaluations made by Istomin with regard to hydrogen ions have shown that even at 1000 km these ions (as well as those of helium) make no noticeable contribution to the composition of the ionosphere. However, Mg^+ , Ca^+ , Si^+ , and Fe^+ ions were detected

in a narrow range of altitudes (from 100 to 110 km). These ions are undoubtedly the products (debris) of disintegrating meteoritic matter.

Results of an analysis by A. A. Pokhunkov and coworkers of neutral gas particles at altitudes of 200 to 210 km can be summed up as follows: In the middle latitudes of the European USSR at altitudes of the order of 100 km, gravitational separation of nitrogen and argon gases was noted. Atomic oxygen was recorded from a minimum altitude of 100 km, its concentration growing up to an altitude of 210 km. For a correct understanding of processes occurring in the high atmosphere, it is important to know the state of the basic component, nitrogen. Investigations by Pokhunkov have shown that up to altitudes of 200 to 210 km, nitrogen is not dissociated into atoms, but remains primarily (99%) in the form of the inert molecule N_2 . Analysis of neutral gases also showed that neither hydrogen nor helium could be found in amounts exceeding 10^6 particles per cubic centimeter up to altitudes of 210 km.

Density and temperature are also very important in the physics of the upper atmosphere. Direct measurement by rocket- and satellite-borne instruments at altitudes exceeding 100 km have been responsible for changing concepts of the structure of the upper atmosphere. As a result of investigations conducted in the Soviet Union under the direction of V. V. Mikhnevich, unique data are now available on the density of the atmosphere up to altitudes of 600 to 700 km. The data obtained by the third Soviet satellite deserve particular attention. Fig. 3 is a diagram showing summarized results on density, while Fig. 4 shows temperatures of the high layers of the atmosphere, as obtained by V. V. Mikhnevich.

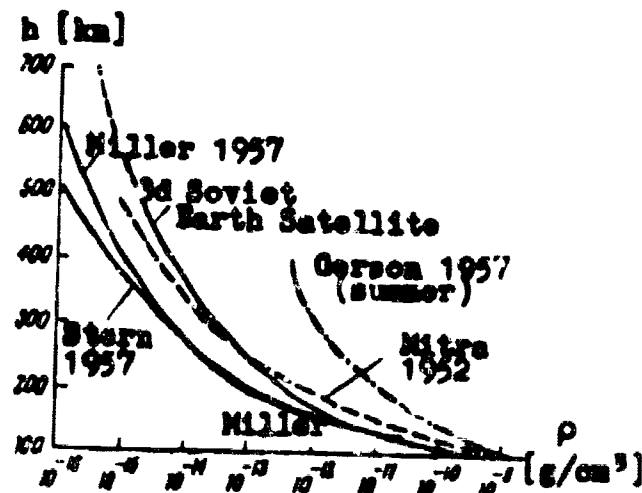


Fig. 3. Comparison of the results of investigations of the density of the atmosphere obtained by rockets and satellites, with pre-rocket age notions of the structure of the atmosphere

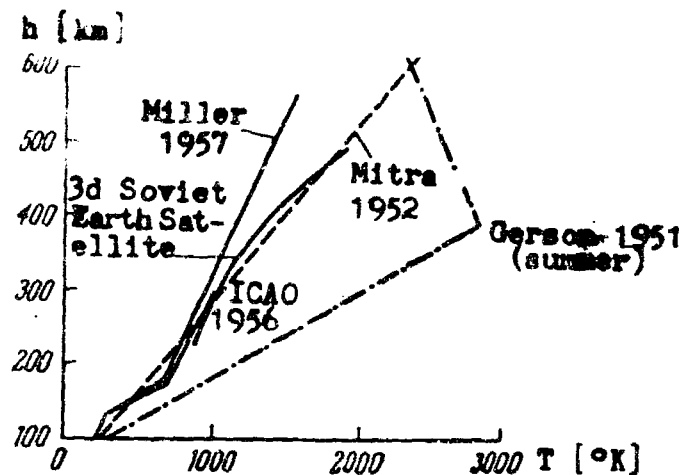


Fig. 4. Temperature of high layers of the atmosphere

Data obtained by Soviet researchers and presented on these diagrams have been incorporated into the tables of the Universal Standard Atmosphere, now under preparation by a special international commission.

The investigation of micrometeorites stands somewhat apart from the study of the structural parameters of the atmosphere. Micrometeorites, which penetrate the earth's atmosphere in huge quantities at high velocities (up to 70 km/sec), interact with the gases of the atmosphere and may be the source of a number of physical and chemical phenomena. Every year, more and more scientific data are published which deal with this interaction. However, until now no direct observations could be made.

Further breakthroughs in studies of the atmosphere will entail increased high-atmosphere soundings and an enlarged sounding network, so that it will be possible to investigate in greater detail the space--time characteristics of the upper layers.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph 2 d ✓

SOURCE: Pochtarev, V. I. Application of the Kotel'nikov theorem to the study of geophysical phenomena. Geomagnetizm i aeronomiya, v. 1, no. 2, 1961, 278-280.

In geophysics, we often face the necessity of studying a continuous process by means of a sequence of individually observed values. In such a case, the problem arises concerning the amount of information needed to represent in space or time a geophysical phenomenon or process with a given degree of accuracy. In a magnetic survey, for instance, it is essential to determine the minimum density of the network of stations and traverses which is still adequate for demarcating a certain class of anomalies. Similar problems arise in gravimetry and in meteorology, hydrology, and oceanology when a hydrometeorological or oceanographic network is being planned. In all these cases, we must know beforehand the number of points or stations required for a given area.

In addition, when studying the nature of a process as it develops in time, we may have to ascertain the amount of information required for a given period. Variations in the earth's magnetic field, geomagnetic activity, and the ebb and flow of the ocean tides are some of these processes. Because of the lack of a strict criterion for adequacy, the problem is being solved in geophysics with approximation in most cases. This often results in a waste of time and effort or in incomplete understanding of the process under study.

The author believes that in solving such problems the arbitrary element can be eliminated, and a rigid criterion regarding the adequacy of information can be established. In the theory of information, which serves as a basis of today's radio communication, the problem of the minimum sufficient amount of individual signals related to continuous processes is solved rigidly. The theoretical foundation for this, laid down by V. A. Kotel'nikov, is presented in a paper by M. P. Dolukhanov.

We assume that the function $f(t)$ expresses some physical process occurring in space or time. If $f(t)$ satisfies Dirichlet's requirements and does not contain frequencies exceeding F_{cps} , it is determined by all ordinates that are separated from each other by $1/F$ seconds. If function $f(t)$ works during time T , it can be fully represented by means of $2 T$ individual ordinates. It follows from this theorem that if we have to transmit information on a continuous physical process the continuous function $f(t)$ representing this process can be wholly expressed by means of a certain number of individual impulses.

To determine the optimum number of impulses in

accordance with Kotel'nikov's theorem, the function $f(t)$ must be broken down into a Fourier series. If $f(t)$ is a periodical function with period T and has a limited spectrum, then

$$f(t) = \sum_{k=0}^n a_k \cos \frac{2\pi kt}{T} + b_k \sin \frac{2\pi kt}{T},$$

where a_k and b_k are Fourier coefficients. If the function is not periodical, it still can be represented within the given interval by the F series:

$$f(t) = \sum_{k=0}^n a_k \cos \frac{2\pi kx}{l} + b_k \sin \frac{2\pi kx}{l}.$$

We assume that within the interval l the function $f(t)$ is represented by the Fourier series (with sufficient accuracy) by means of n harmonic curves.

If the frequency spectrum $f(t)$ covers the band from F_1 to F_2 , where the minimum frequency of the spectrum of the function $f(t)$ is F_1 and the maximum is F_2 , then the number of impulses N needed for providing enough information on a given process will equal

$$N = 2T\Delta F \quad (\Delta F = F_2 - F_1).$$

For the case where $F_1 = 0$,

$$N = 2n \quad (n = TF_2).$$

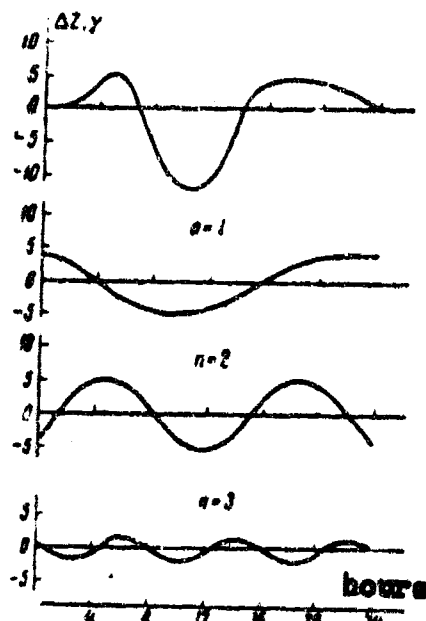
If we want to establish not the number of impulses but the time interval between them Δt , the latter can be determined easily from the expression

$$\Delta t = \frac{1}{2F_2}.$$

It is thus possible to represent by means of the Kotel'nikov theorem any continuous process with a finite spectrum by a sequence of impulses. A close relationship can be said to exist between the statement of the problem for studying certain geophysical phenomena and the theory of information in communication.

The following example should demonstrate that some methods of the information theory, particularly the Kotel'nikov theorem, can be successfully applied in geophysics.

The task is to determine the time interval for which data are needed on the diurnal variations of the earth's magnetic field at a given point in order to obtain a full representation of these variations during a period of 24 hours. Function $f(t)$ is plotted on the diagram (see illustration, upper curve) at a given place from the data of a given station.



After expanding the curve in the Fourier series, we determine that

$$f(t) = \sum_{k=0}^{n=3} a_k \cos \frac{2\pi kt}{T} + b_k \sin \frac{2\pi kt}{T}, \quad f_0 = 0, f_{\max} = 3,$$

$$N = 2n = 6;$$

i.e., the adequate number of individual signals showing the variations of the magnetic field on calm days at a given point equals 6. Since in this case the period $T = 24$ hours, then $\Delta t = T/N = 4$, which means that time intervals of four hours are sufficient for representing $f(t)$ of the diurnal variations. The method of the exact determination of Δt is of ever-growing importance in geophysics, where automation and radio communication are being introduced on a wide scale.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph # (

SOURCE: Khzmalyan, K. A. Popularization of hydro-meteorological knowledge. Meteorologiya i gidrologiya, no. 2, 1960, 51-53.

Since 1959, the Soviet press has been giving extensive coverage to scientific activity in the field of hydrometeorology. During the period from August to October 1959, more than 200 articles, reviews, and reports were published in the national, republic, and regional newspapers.

Of particular interest were reports dealing with research on atmospheric electricity conducted by the Main Geophysical Observatory and the successful experiment in the use of radio-controlled aircraft models for meteorological investigations also conducted by that institution.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1. Paragraph 6 *d*

SOURCE: Dietze, Gerhard. The importance of artificial earth satellites for atmospheric-optical research. *Zeitschrift für meteorologie*, v. 12, no. 3, 1958, 73-84.

ABSTRACT: On the basis of geophysical and astronomical data, the author discusses questions concerning the types of atmospheric-optical measurements which are currently being made, or which will be made by means of artificial satellites. An earth satellite can be used for atmospheric measurements in two ways: (1) as a secondary source of light, which it reflects from the sun; and (2) as a carrier of optical measuring instruments.

The conditions in the three illumination zones -- the umbra, the penumbra, and the shadow-free zone -- are analyzed, and their relations with atmospheric optical effects are discussed. These factors, in association with the reflective properties of the satellite and the light extinction, determine the degree of satellite luminosity which can be calculated by means of diagrams and tables. The satellite, when used as a carrier of optical measuring instruments, affords certain advantages which are not available when measurements are made from the earth. For example, sunlight can be measured before it is diffusely reflected by the earth's atmosphere. On the other hand, satellites have limitations. One of these is that it must be equipped with instruments which are able to withstand the impact of starting acceleration.

The appearance of satellites as new instruments of geophysical research was somewhat sudden. Before the first satellite was launched, there had been no broad exchange of ideas on its possibilities for many fields of geophysical research. It follows, then, that these possibilities have by no means been explored to the fullest extent.

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR),
Report 1. Paragraph 7

SOURCE: Mirtov, B.A. Investigations of the composition of the high layers of the atmosphere conducted in the Soviet Union by means of rockets. IN: HIS Gazovyy sostav atmosfery zemli i metody yego analiza (Gaseous composition of the earth's atmosphere and methods for its analysis). Moskva, Izd-vo Akademiya nauk SSSR, 1961. 105-143.

Introduction

Rocket investigations of the chemical composition of the atmosphere were begun in the Soviet Union in 1949, i.e., at approximately the same time that similar work was undertaken abroad.

The work conducted in our country differs from foreign research as to the methods of taking atmospheric samples (the sample is taken at a considerable distance from the rocket) and the analysis of the samples.

Powerful Soviet rockets, capable of lifting heavy payloads, are equipped with special mortars, into which automatic capsules are inserted; these capsules carry the research instruments (including cylinders for taking samples). At an altitude specified in the program apparatus, the capsules are thrust from the mortar and begin free flight in the earth's gravitational field. Since the axis of the mortar is set at a particular angle to the axis of the rocket, the capsules are thrust to one side of the rocket's path. The capsules leave the rocket behind, and thus leave the danger zone where the composition of natural gas may be highly distorted by "parasitic" gases associated with the rocket. The ejection of the capsule from the mortar occurs even before the rocket reaches the altitude specified for the taking of the samples. This is done so that the capsule can withdraw as far as possible from the body of the rocket and be "ventilated" as much as possible and freed from the residue of contaminating gases which are always present in small quantities in the capsule. After all of the work on the automatic capsule has been completed, and it is on the descending portion of its trajectory, a parachute is opened and all of the fragile glass apparatus is carefully lowered to the earth.

Unlike the American and British researchers, who use the physical-chemical method for analyzing the samples obtained, Soviet researchers use the spectral method. This method makes it possible 1) to make a quantitative analysis of the principal components (oxygen, nitrogen, argon) in volumes of gas measured in tenths or even hundredths of a cubic millimeter (at normal surface pressure), and 2) to investigate the composition of the atmosphere to altitudes of the order of 110 km with satisfactory accuracy (5 to 8%).

The special characteristics of rocket investigations of the composition of the atmosphere at great altitudes are such that the entire experiment may be broken down into three parts: sampling, storage of samples, and

analysis of samples. Since each of these aspects has taken on independent significance, they are discussed separately in the next three sections.

1. Sampling

We used glass cylinders for taking the samples of gas; these have special seals. The cylinders were placed in a capsule which the rocket delivered to the required altitude.

Capsule. The capsule, whose exterior is shown in Fig. 1, is a metal cylinder approximately 3 m long and 40 cm in diameter. The capsule is made up of several independent compartments. The top compartment is the parachute compartment 2; below this is the unhoused and easily ventilated compartment 3 which carries the measuring apparatus; next comes the instrument compartment 5, and finally, the power compartment 7. The cowl of the parachute compartment includes a system of braking plates which orient and brake the capsule until the parachute opens. At the end of the capsule are a thin metal corrugated cone and steel rods which serve as shock absorbers for softening the impact of the capsule when it strikes the ground after its parachute descent.

The entire design of the capsule is geared to two principal requirements: to carry out the set program of research, and to maintain vacuum purity. The latter, to a very considerable extent, depends on clean, easily washable surfaces, and the absence of "pockets" in which near-surface air could be transported aloft and there, slowly escape from beneath some compression and systematically contaminate the surrounding space. Therefore, the auxiliary compartments 2, 5, and 7 are made rigidly airtight, while compartment 3, on the contrary, is made as open as possible for the purpose of permitting the measuring instruments to have free access to the surrounding gas.

Vacuum purity is of decisive importance for taking samples experimentally. The parachute can cause very great annoyance in this respect. The parachute fills its compartment and is a huge reservoir of near-surface air. During the ascent of the rocket, the great amount of tightly packed material cannot be deaerated, and a special system is therefore used to hermetically seal the parachute compartment. The entire parachute compartment is covered by a protective metal hood which is fitted on a base plate, thus hermetically sealing the entire source of danger. The protective hood is cast off just prior to the opening of the parachute, when the entire program of scientific research in the capsule (including the taking of samples) has long been completed.

It is necessary to maintain atmospheric pressure in compartments 5 and 7 in order to ensure the normal operation of all the automatic instruments and power sources enclosed therein. The smooth surfaces of all the compartments make it easy to thoroughly wash them and free them from grease before they enter into flight.

The unhoused compartment, which carries the cylinders for the taking of samples, is shown separately in Fig. 2. Metal, glass, and porcelain

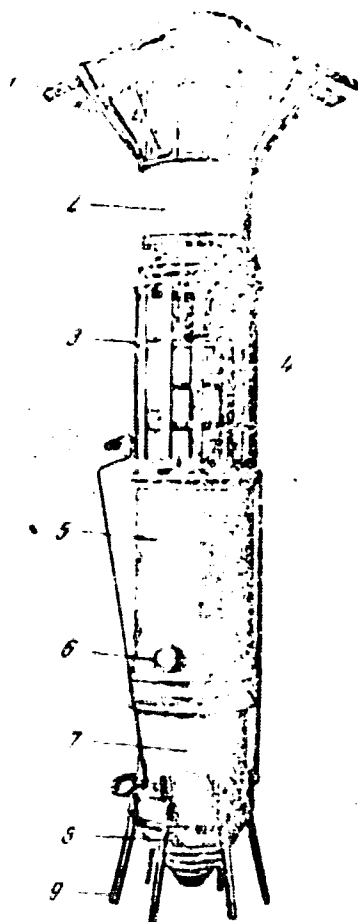


Fig. 1. Automatic capsule

1 -- braking plates used in the recovery system; 2 -- parachute compartment; 3 -- unboxed compartment; 4 -- glass cylinders; 5 -- instrument compartment; 6 -- portholes to admit light for the cameras; 7 -- power compartment; 8 -- shock-absorbent cone; 9 -- steel rods for absorbing shocks during the landing of the capsule.



Fig. 2. Unboxed compartment of capsule with cylinders for taking samples for altitudes of less than 100 km

are used in this compartment to ensure an adequate vacuum; a minimum amount of vacuum rubber is permitted in the form of thin cushions used when attaching the glass cylinders to the inner metal crosspiece. The required electrical voltage and the commands from the programming equipment are conveyed from the instrument compartment and the power compartment to the cylinder seals through special vacuum outlets by means of bare copper leads mounted on porcelain insulators.

A new model of the unhoused compartment has recently been devised. It makes it possible for the cylinders to be extended somewhat outside the body of the capsule. Fig. 3 is a photograph of such a compartment. The re-vamping of the unhoused compartment was deemed necessary because, at the great altitudes under investigation, the results of the analysis of the samples were influenced by the liberation of gases from these surfaces of the capsule which were directly accessible to the inlet of the cylinder. At altitudes of the order of 110 to 115 km, the free paths of molecules are so great that the molecules, in moving away from the "apparent" surface of the capsule, can, without hindrance, enter the cylinder and distort the composition of atmospheric gas. It is therefore necessary that the inlet of the cylinder be oriented in such a way that the sample will, to a considerable extent, be safeguarded from undesirable contamination by gases*.

Before the flight the assembled capsule is carefully washed with alcohol and thoroughly wiped. It is then delivered to the rocket in a special jacket in preparation for the launching. The capsule is inserted in the mortar in such a way that, upon removal from the special protective jacket, its surface will come into as little contact with the crew's hands as possible. The purpose of these operations is to minimize the contaminating influence of the capsule on the surrounding medium, the parameters of which must be measured.

Cylinders. In contrast to the Americans, who use steel cylinders for sampling, glass cylinders are used in our research. The difference is by no means accidental. When making an analysis of gases for oxygen we should not use metal as a container for the storage of the sample. Because of oxygen's great chemical activity, it usually oxidizes metal surfaces and is lost for analysis^{**}. The walls of a glass cylinder are in this respect unquestionably superior. Unfortunately, there were great difficulties associated with the safe recovery of the glass cylinders. However, these difficulties have been eliminated and have made it possible to get a considerable number of samples from altitudes of the order of 100 km.

* For lesser altitudes (less than 100 km), the extension of cylinders outside the capsule proper is not of great importance because the free paths of molecules are short and the amount of surrounding gas is great enough to permit the influence of desorption from the surface (a well-finished surface) to be ignored.

** As already mentioned, this explains the absence of oxygen in the steel cylinders used by American researchers.

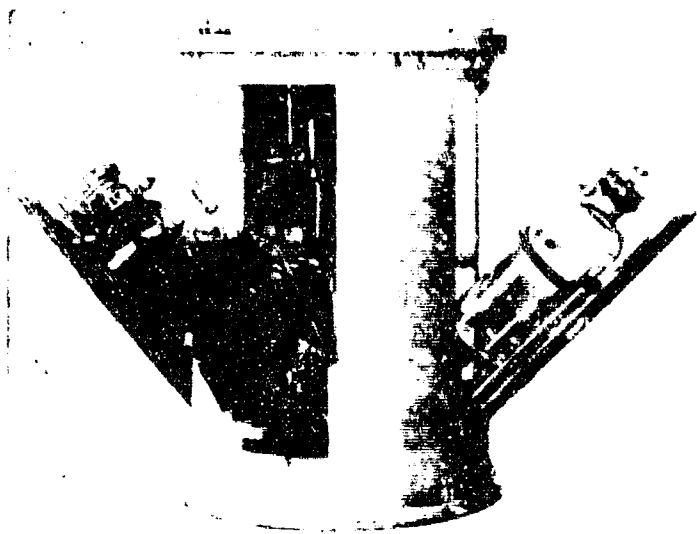


Fig. 3. Compartment of capsule with "extensible" cylinders for taking samples from altitudes of more than 100 km

The shields are closed before and after the samples are taken.

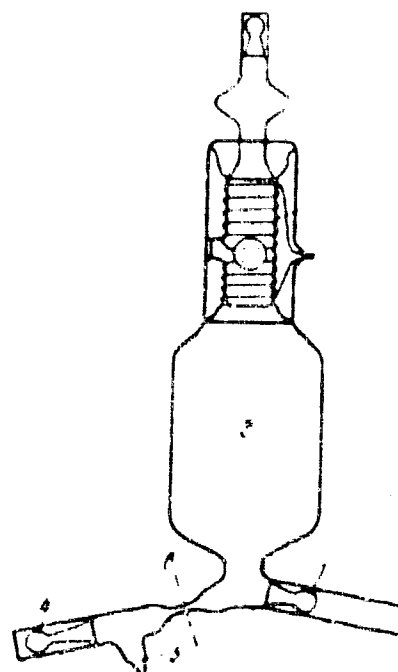


Fig. 4. Drawing of a small glass cylinder

1 -- tubular extensions for fusing the cylinder into the analytical vacuum pump; 2 -- seal heater; 3 -- cylinder; 4 -- spare tubular extension for fusing the cylinder to the pump during the control evacuation; 5 -- point at which the cylinder is removed after the initial evacuation; 6 -- constriction for removing the cylinder after the control evacuation.



Fig. 5. External appearance of the large and small glass cylinders for the taking of samples

The cylinders are supplied with seals using ceresin.

Thin-walled cylinders with a capacity of approximately three liters were used in the work. From altitudes of 80 to 95 km these cylinders furnished the laboratory with 3 to 4 cubic millimeters (at normal air pressure). Since spectral analysis makes it possible to analyze far smaller volumes of gas, small cylinders with a capacity of 400 cm³ were used in the experiments. Fig. 4 is a sketch of such a cylinder. Cylinders of small capacity, being less fragile, have an advantage over large cylinders when they are being recovered. Fig. 5 shows the exterior of both cylinders.

The preparation of a glass cylinder for a flight involves two stages: the preliminary stage and the launching stage.

In the preliminary stage the cylinder, provided with a seal (to be described below), undergoes special thermal-vacuum processing in order to eliminate moisture and various kinds of occluded gases from it. The cylinder, having been washed with alcohol, is evacuated for 8 to 10 hours with a vacuum pump until a pressure of the order of 10^{-6} mm Hg is attained. At the same time the glass is heated to a temperature of 300 to 400°C.

In the launching stage we are concerned with the fact that the processed cylinder is not usually sent into flight at once. It may lie at rest for a considerable time (months) before it is used. During the interim, a certain amount of "parasitic" gas may be liberated within the cylinder. The cylinder is therefore evacuated again immediately before the launching. For use in such repeated (control) evacuation, the cylinder has an extra outlet by which the evacuated cylinder can be fused to the pump and then opened without air entering. This operation is carried out on the day before the flight by using the mobile high-vacuum pump pictured in Fig. 6*. The cylinder is not reheated on this occasion.



Fig. 6. Portable high-vacuum pump

* The pump was designed by A.A. Baykov.

The method used for preparing the cylinder possesses the positive advantage of making it possible to make a preliminary checking of the airtightness of the seal before the experiment gets under way. If it is found that there is increased pressure in the cylinder at the time it is opened for the check (10^{-4} mm Hg or more), the cylinder is rejected and is not used.

Seal. The seal is the most important part of the cylinder. The use of glass cylinders requires the use of glass seals because metal stoppers can nullify all the advantages of the glass which were mentioned above.

In view of the fact that the volume of gas entering into the cylinder is measured in the cubic millimeters, and even hundredths of cubic millimeters, the seal should meet a series of rigid requirements:

1) The seal should be fully airtight both before and after the sample is taken;

2) During processes associated with the operation of the seal, there should be no liberation of "parasitic" gases in volumes dangerous for analysis of the sample. If a lubricant is used in the seal it should not enter into reaction with the gases of the sample;

3) The seal should have a large mouth but a short inlet. If this requirement is not observed, in those regions of the atmosphere where the free paths of molecules become greater than the dimensions of the inlets (Knudsen effect), there may begin a forced liberation of gases in accordance with their atomic weights; the light gases will penetrate into the cylinder more rapidly than the heavy ones;

4) The seal should be ready for use for a long time after its "charging." This period of time, like storage time, may be a matter of months. It is extremely desirable to have a seal which can be used repeatedly so that it may be checked frequently in the laboratory;

5) The seal should operate automatically and should be as simple as possible; it should not be cumbersome, nor should it consume a great amount of power from the batteries.

The creation of a seal meeting the above requirements was quite a complex matter. Many versions of seals were tested for the solution of this problem; here are some of them:

1) An ordinary vacuum seal with a vacuum lubricant;

2) Remelting of the glass inlet of the cylinder by means of an electric heater, with subsequent flattening of the heated part of the tube;

3) Remelting of the glass inlet of the cylinder by an electric heater, with the tube being plugged by a dry glass plunger; fusing of the polished surfaces;

4) A polished glass plug with silver chloride used as a sealer;

5) A seal based on "optical contact;"

- 6) A vacuum seal with picene used as a lubricant; the picene melts when the seal is in use;
- 7) A mercury seal;
- 8) A vacuum seal with ceresin used as a lubricant (melting);
- 9) A seal with a flat surface, ceresin being used as a lubricant (melting).

By no means did all these possibilities prove to be suitable for practical utilization. For example, it was found immediately that an ordinary vacuum seal with a vacuum lubricant could not be used. The reasons for this are as follows: The lubricant enters into a chemical reaction with the oxygen in the sample, and during prolonged storage it dries out and the seal can no longer be turned easily. The airtightness of the seal is destroyed when the lubricant dries out. The drying-out entails the evaporation of the volatile fractions of the lubricant. These volatile fractions in turn enter the cylinder and ruin the sample.

All seals prepared from fused glass could be used for sampling at low altitudes (up to 30 km) but were completely unsuitable when it was necessary to take samples from altitudes of the order of 100 km. As is well known, large volumes of gases such as CO, O₂, CO₂, etc., are liberated during the melting of glass. In the case of the melting of narrow capillaries when the density of the surrounding medium is high (low altitudes), the gases liberated during the heating process cannot significantly influence the composition of the sample taken. The reverse picture is observed when samples are taken at high altitudes: the low pressure in the surrounding medium (10^{-6} to 10^{-8} mm Hg) and the need for melting the wide inlet (see above) lead to a strong contamination of the gas sample.

Approximately the same considerations might be mentioned in respect to the use of picene and silver chloride. The melting of these substances is accompanied by the abundant liberation of parasitic gases. Not only does silver chloride require a rather high temperature and an extraordinarily rigid heat regime for it to melt, but in addition it does not always yield the required vacuum seal.

The attempt at designing a seal to be used in the airtight sealing of the inlet of the cylinder on the basis of an optical contact between two polished surfaces was unsuccessful because the use of this arrangement would require too heavy and complex an apparatus and would provide no guarantee of reliable operation of the seal.

Only three of the seals mentioned in the list are suitable for use in practical work: the mercury seal, the vacuum seal lubricated by ceresin, and the flat-surfaced seal lubricated by ceresin. We will give a brief description of the seals used.

The mercury seal illustrated in Fig. 7 is a system of dry plungers, carrying springs, and mercury. Its principle of operation can be described as follows: After the evacuated cylinder is opened and the sample is taken, the inlet is closed by the two internal dry plungers, with the space between them being filled with mercury. The mercury plug formed in this manner is an excellent vacuum seal.

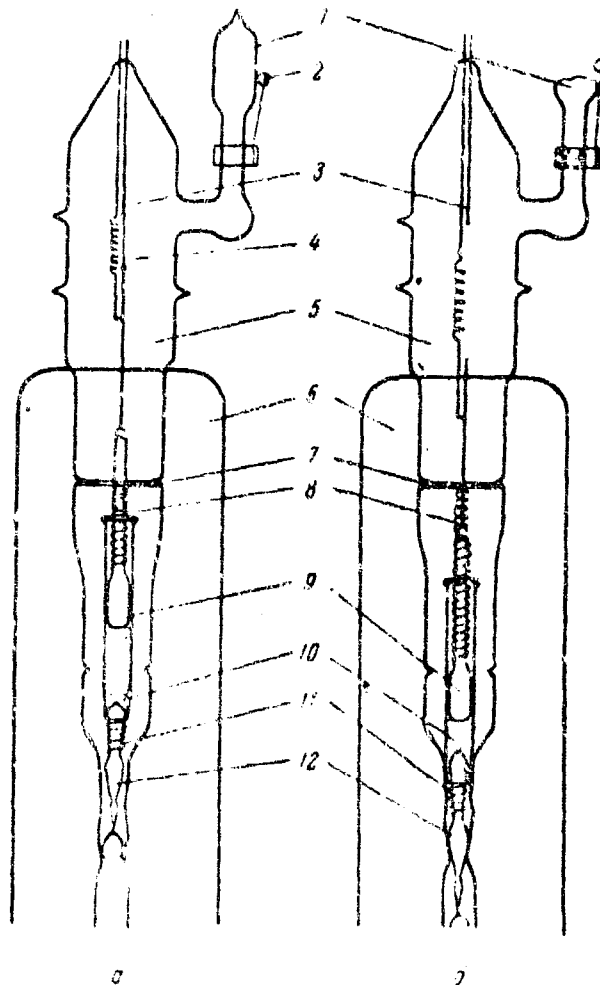


Fig. 7. Diagram of the mercury seal (a) before taking sample and (b) after taking sample

1 -- "cap" for inlet; 2 -- small hammer which breaks the "cap"; 3 -- electrodes which hold the internal parts of the seal in a raised position; 4 -- section of an electrode melted by the current at the moment of closing of the cylinder; 5 -- outer part of the seal; 6 -- throat of the cylinder; 7 -- supporting washer; 8 -- spring; 9 -- plunger; 10 -- pump filled with mercury; 11 -- spring; 12 -- plunger of outlet valve.

The mercury seal, however, has one substantial shortcoming: it is heavy and fragile. The mercury seal was therefore replaced by a simpler and more convenient seal using ceresin.

This seal is an ordinary vacuum seal with high-quality polishing and an inlet of approximately 1 cm². Ceresin is used as a lubricant for the seal. Ceresin (mineral wax) is a mixture of solid high-polymer paraffin hydrocarbons of the series $C_n H_{2n+2}$ and is a solid at room temperature; it melts, depending on distillation, at 60° to 100°. Our work has made it clear that ceresin distilled in a vacuum in both the molten and solid states does not release "parasitic" gases in quantities sufficient to influence the results of analysis of the sample. At the same time, because of its chemical inertness, ceresin does not enter into appreciable reaction with the principal components of the sample (N_2 , O_2 , A). The mechanical properties of ceresin are also very valuable: in the solid state it possesses great mechanical strength, and in the liquid state it has an extremely small coefficient of viscosity. Because of this the plug in the seal turns very easily in the molten ceresin and sets very tightly as soon as the ceresin cools. If the plug is highly polished, the solidified ceresin creates a perfect vacuum seal.

The design of the seal itself is quite simple (Fig. 8). The seal turns by two spiral springs 3. On the sleeve 5 of the seal there is mounted a nichrome spiral 6 -- the heater, which is insulated by the glass jacket 8 from the surrounding space. In addition, the seal is supplied with a locking device 2 which holds the seal in the required position and then frees it. This "stopper" is a short wire which holds the plug of the seal while it is being turned. By melting the wire with an electric current at the appropriate time, it is possible to free the seal plug for subsequent turning. Before opening, the seal is in a "raised" position, i.e., the plug closes the inlet and is firmly seated in the cold ceresin and the springs are taut. When the seal is opened, the heater melts the ceresin and frees the plug; the latter, turning under the influence of the springs for a quarter turn, opens the inlet and is held in this position for 10 seconds by the "stopper." During this time the gas enters into the evacuated cylinder and the pressure in it becomes equal to that on the outside. Then the "stopper", holding the plug, is melted by the current, and the plug, on turning still more, again closes the inlet to the seal; the heater is switched off, and the solidifying ceresin creates the necessary vacuum seal.

The switching on and off of the heating device and the actuating parts of the seal is accomplished by a distributor mechanism at strictly determined moments. Because of this the altitude at which the sample is taken will always be known precisely. In addition to the computed time curves, special bulbs light up in the instrument compartment when the cylinders open and close; these, together with the other instruments, are photographed. Signal flares help to determine more precisely the altitudes at which the samples are taken.

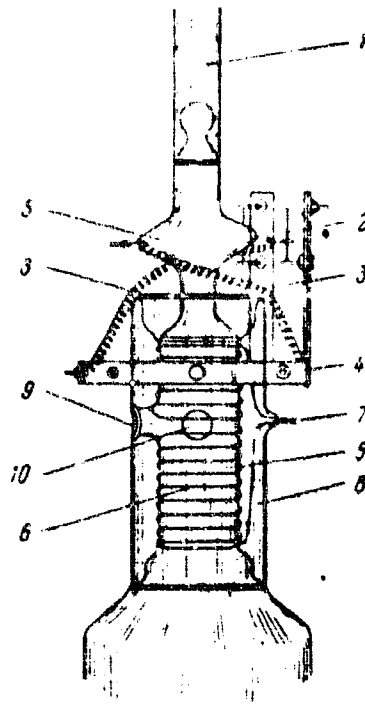


Fig. 8. Vacuum seal employing ceresin

1 -- tube for fusing the cylinder containing the sample to the vacuum pump;
 2 -- locking mechanism; 3 -- springs;
 4 -- metal support; 5 -- seal connection; 6 -- electric heater; 7 -- leads for electric heater; 8 -- outer jacket;
 9 -- inlet of cylinder; 10 -- inlet in seal plug (the position shown is when the seal is closed).

The most acceptable seal is one with a flat outer surface which makes it possible to have a large inlet and a short throat in the cylinder. This seal is shown in Fig. 9. Its operating principle is essentially as follows: A flat flange is turned on the throat of the glass cylinder in such a way that a hollow space remains within the flange. A nichrome spiral is fused in this space, with the ends leading outward. The spiral leads to the heater which warms the ceresin. The outer side of the flange is polished on a plane polishing lathe; the accuracy of the plane-parallel polishing is held within the limits of 1 to 2 microns. The top of the seal is also carefully polished. The two surfaces, polished in this manner and lubricated with a thin layer of ceresin, ensure a good vacuum seal. Unlike an ordinary vacuum seal, the flat

surface holds a vacuum when the ceresin is still molten, even when the difference of pressure within and outside the closed cylinder attains 1 atmosphere.

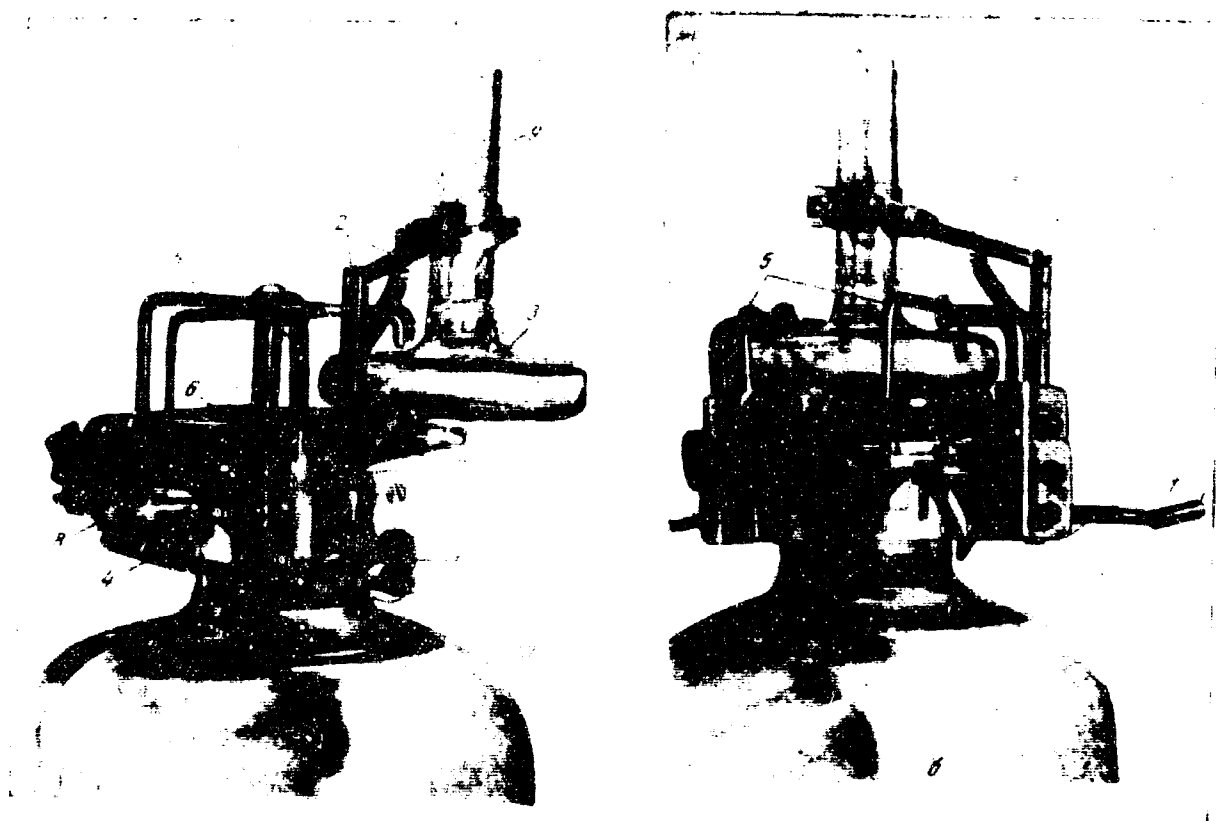


Fig. 9. Position of seal with flat surface in the cases of an open (a) and closed (b) cylinder

1 -- opening spring; 2 -- turning mechanism; 3 -- top of seal; 4 -- closing spring; 5 -- devices to hold down top of seal securely; 6 -- flange of throat of cylinder; 7 -- electric heater; 8 -- terminal unit for electrical supply; 9 -- upper tube for fusing of cylinder into vacuum pump; 10 -- cylinder for taking samples.

The mechanism proposed by A.A. Baykov for opening and closing the inlet to the cylinder (diameter 3 cm)* can also be used with a system of spiral springs. The opening of the cylinder occurs automatically when the ceresin is melted and the top is drawn to one side by the taut spring. After the required exposure

* It is necessary to have an unwieldy seal in order to make such an opening in an ordinary vacuum seal. Thus, the diameter of the plug of such a seal in the opening should be about 10 cm.

and melting of the appropriate locking device, the top is again returned to its position, but by means of another spring. In order to safeguard the seal from possible arbitrary opening during the period of time after the taking of the samples and the cooling of the ceresin, the top is held tightly by a special device which prevents lateral (slipping) movements*. The transmission of the necessary voltage and the command is accomplished in the usual manner from the programming mechanism located within the capsule's instrument compartment.

2. Storage of Samples

Some time passes between the moment when the sample is taken and the moment when it is analyzed. It is therefore necessary to make careful study of the method for storing the collected microquantities of gas in order to ensure that there will be no change in their composition.

At altitudes of an order of 100 km, where the samples are taken, the free path of molecules attains several centimeters. Therefore, in an overwhelming majority of cases, the molecules of gas which enter the cylinder constantly collide with its walls. Under these conditions the phenomena of sorption are most clearly expressed and can result in a considerable change in the composition of the trapped gas. At the same time, under the indicated conditions, the phenomena of desorption of "parasitic" gas by the walls of the cylinder are facilitated, which can also change the initial composition of the collected sample.

In order to avoid the active manifestation of these undesirable processes, or at least to minimize their harmful influence, every effort should be made to shorten the time lapse between the moment when the sample is taken and the moment when it is analyzed. In the work described the time was decreased to 2 to 5 days, but even this apparently is not adequate. On the other hand, the retention of collected samples -- their "preservation" over a long period of time -- is a problem of independent importance. There always remains the necessity for storing the samples in the laboratory for repeated analysis, and for storing the standard (reference) mixtures required in this work.

The above considerations have made it necessary for us to devise the "capillary method" for prolonged retention (preservation) of small volumes of gas mixtures.

The capillary method for the storage of small volumes of gas. As is known, the sorption phenomena are associated with the surface surrounding the gas. Therefore, if we propose to store a sample of gas in its initial composition, it is necessary to decrease to a minimum the surface with which the gas is in contact. This can be accomplished, provided that immediately after the sample is taken it is transferred from the cylinder, where the pressure is

* Movements may occur under the influence of pressures appearing as a result of the high velocities of the capsule during its entry into the relatively dense layers of the atmosphere.

maintained to the thousandths of a millimeter of a column of mercury, into a narrow capillary and compressed there to atmospheric pressure. The transfer of the gas from the cylinder into the capillary is accomplished by a vacuum pump using mercury (see Section 6). After the compression of the gas in a capillary there still remains a small drop of mercury which seals the capillary airtight. Fig. 10 shows the glass capillary, in which a small sample of

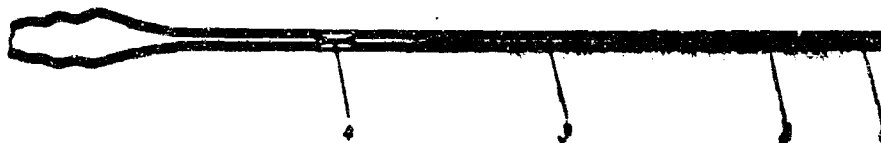


Fig. 10. Capillary with sealed-in gas sample

1 -- sample of gas compressed to atmospheric pressure; 2 -- mercury plug; 3 -- capillary void; 4 -- construction to hold back mercury.

gas is sealed, after it has been cut from the pump. Samples can be preserved in such capillaries for a long period of time. Our experiments have demonstrated that over a period of two to three years a sample (ordinary air) does not change its composition when sealed by mercury. An exception to this is a sample containing helium which slowly escapes from the capillary by diffusion through the glass (quartz)*. With a decrease in the volume of the vessel holding the sample, there is, generally speaking, an increase in the ratio of the internal surface to volume. It can therefore be demonstrated that the conditions for preservation of a sample and the conditions surrounding its analysis, from the viewpoint of the influence of the surface on the composition of the sample, are less favorable in a small space than in a large one. However, such an assertion is erroneous when applied to the microanalysis of gas mixtures where the experimenter has at his disposition a small, limited volume of gas. When a volume of gas is compressed, its quantity remains unchanged, regardless of the capacity of the vessel in which it is contained. However, the surface-liberating or -absorbing gas will be considerably reduced when the volume of the container is small. For a given volume of gas, whether entering an analyzer or in storage, it is not the ratio of the volume of the vessel containing the gas to its internal surface which is important, but rather the absolute value of the latter.

When transferring the gas sample from the cylinder into the narrow capillary, it is possible to decrease the sorption surface of the glass by many orders. For example, the transfer of a gas at a pressure of 10^{-3} mm Hg from a cylinder with a capacity of 3 liters (whose surface is about $2 \cdot 10^5$ mm²) into

* If the capillary contains pure helium, the diffusion of helium through various types of glass and quartz can be easily and precisely estimated from the decrease in the length of the column of gas in time.

a capillary with a diameter of 0.3 mm, where at atmospheric pressure this same gas occupies a volume of 0.3 mm³ (surface about 3 mm²), makes it possible to decrease the harmful surface by more than 50,000 times.

It goes without saying that the storage of samples under these conditions is extremely advantageous.

When the capillary method is used, a positive role in the preservation of the gas is also played by the gas in the capillary, which is under great pressure. Under these conditions the free path of a molecule becomes very small. At atmospheric pressure the paths do not exceed several millionths of a centimeter ($\sim 5 \cdot 10^{-6}$ cm). The majority of the collisions therefore do not occur with the wall of the container, as was the case earlier, but between molecules of the gas. It might be added that the walls themselves now present considerably less danger for the collected sample because they are coated by a stable film of "preserved" gas which is a hindrance to further sorption phenomena.

The storage of a gas sample in a capillary offers us still other important advantages. One of them is that the capillary holding the sample is at the same time an excellent pressure gage. This makes it possible to determine with great accuracy the pressure in the cylinder containing the sample. By knowing the diameter of the capillary and by measuring the length of the mercury-sealed column of gas with a calibrated lens, it is easy to determine the volume which the gas occupies in the capillary at a given atmospheric pressure. By knowing the volume of the cylinder from which the gas was forced into the capillary, it is possible to determine the initial pressure of the gas in this cylinder. Thus, the necessary operation of measuring the initial pressure in the cylinder taking the high-level sample, involves no more than the ordinary measurement of the length of the column of gas in the capillary. It is known that this measurement can be made with a relative error of 2 to 3%. In other words, the capillary method makes it possible to determine pressure in a cylinder with an accuracy of 2 to 3%. This degree of accuracy must be regarded as high, since available pressure gages used in vacuum work for the measurement of pressures in the vicinity of 10^{-6} mm Hg can at best ensure an accuracy of 20 to 30%.

The advantages of the indicated method for the measurement of pressure become particularly clear when it is necessary to deal with small volumes of gas. The use of any other method will in this case lead either to contamination of the sample and a change in its composition (ionization, thermal, and other pressure gages), or to a large loss of the gas under investigation which fills the volume of the pressure gage (mercury pressure gages, etc.). The capillary pressure gage, being an "absolute instrument", so to speak, is free of such shortcomings.

A substantial advantage of the capillary method is that the gas, once transferred into the capillary, undergoes no subsequent transfer and is thus not contaminated nor does it suffer loss in the vacuum pump. Jumping ahead

* Atmospheric pressure, to which the gas under investigation was compressed, can be measured with an error of less than 0.5%.

somewhat, we might mention that spectral analysis can be accomplished directly in the capillary where the sample is stored. This requires that the necessary pressure -- of the order of 5 to 10 mm Hg -- be created in the sealed volume of gas. This pressure can be produced by withdrawal of the mercury plug by means of evacuation by an ordinary initial vacuum pump to the appropriate distance, earlier determined and fixed by the intake on the capillary. The pressure established in the capillary analyzer is again checked by a simple measurement of the length of the gas column which is closed in by the "plug." After completion of the analysis, the surrounding air is again admitted into the free end of the capillary, and this again returns the mercury "plug" to its initial position. This makes it possible to again restore the capillary-analyzer to a capillary storage tube. The sample can be kept there for years until the next analysis*.

3. Analysis of Samples

There are many methods of analyzing gas mixtures, but all of them become completely inadequate when it is necessary to deal with such small volumes of gas as those taken in the samples collected at great altitudes. There are two ways to solve this problem: 1) by increasing the capacity of the cylinders used for taking the sample, and 2) by increasing the sensitivity of existing methods of analysis without significantly lowering their accuracy**. The first approach, although it appears the simpler, does not lead to the desired end. The use of cylinders with a capacity of 3 liters returns less than 1 cubic millimeter of gas at normal air pressure from altitudes of 95 to 100 km for use in laboratory analysis. If the altitude at which the samples are taken is increased by 10 to 12 km, the amount of gas collected will drop by an order. Consequently, in order to get 0.3 mm³ of gas it is necessary to increase the capacity of the cylinders by an order. It does not appear possible to use glass cylinders with a capacity of 300 liters (and even considerably less) in rocket research for many reasons: difficulties in degasification of the large internal surface and the need for a very large inlet in the cylinder, the great difficulty of installing the cylinders on a rocket and their subsequent safe recovery, etc. Moreover, for practical purposes it is completely unclear how it would be possible to expel all of the gas from a large cylinder (tens of liters) into the apparatus where it is to be analyzed without contaminating the gas. Researchers have therefore been forced to follow a different and more difficult approach -- that of increasing the sensitivity of the presently existing system of analysis and creating new equipment for the microanalysis of gas mixtures which are capable of successfully handling fractions of a cubic millimeter of gas (at normal air pressure).

We have already described in detail the non-Soviet procedures used in such analysis [an allusion to Chapter III of the source from which the present report was taken]. The present report is devoted to a description of the spectral analysis of gas mixtures -- the method which we have used in our country for the

* The indicated method of analysis requires the use of the method of several capillaries; more will be said about this below.

** The method of forced capture of a sample (pumping a gas into a cylinder) presents very great difficulties.

analysis of high-altitude samples.

The principal Soviet research articles on the spectral method for the investigation of gas mixtures, especially by the method of excitation of the gas by a high-frequency discharge, have been written by S.E. Frish and his associates. They have also worked out a method of spectral microanalysis which makes it possible to analyze 2 to 3 cubic millimeters of gas mixture. In these articles particular attention has been given to the analysis of multicomponent mixtures, and this is of particular interest to us. The first samples collected (from altitudes of 60 to 80 km) were sent to the laboratory of S.E. Frish, where they were broken down by O.P. Bochkova into three principal components: oxygen, nitrogen, and argon. After improvements in the method of spectral microanalysis, achieved through joint collaboration with S.E. Frish and O.P. Bochkova, it was found that tenths and even hundredths of a cubic millimeter of gas could be analyzed. Thereafter we concentrated our attention on the improvement of the conditions surrounding the excitation of the discharge, the geometry of the discharge tube (capillary), and the creation of conditions under which the discharge would occur as stably as possible.

After this work had been established on a sound basis, the high-altitude samples were analyzed in our laboratory and in the laboratory of S.E. Frish. In the present report we shall deal primarily with the work which was done in our laboratory. The work done by S.E. Frish and his associates has been published in the articles already mentioned, and the reader may refer to them.

S.E. Frish has proposed the method of a high-frequency "electrodeless" gas discharge for analysis of the samples collected at great altitudes. This method, widely known at the present time, possesses real and decisive advantages for us in comparison with other methods of spectral analysis: the electrodes to which the high-frequency voltage is fed are located outside the discharge tube and therefore do not come into contact with the gases of the sample. This method eliminates all of the major shortcomings inherent in the method of analysis in which internal electrodes are employed (conditions under which the gas in the sample enters into a reaction with the metal surfaces). The presence of internal electrodes has a particularly harmful effect in the case of microanalysis, where the volumes of analyzed gas are very small. However, despite all its advantages, the method of the electrodeless discharge is not free of difficulties of a general nature which are also characteristic of the other methods of spectral analysis of gases, e.g., the ability to get a good repetition of the results of the analysis, the attainment of high accuracy, etc.

The method of analysis in which an electrodeless discharge is employed does not differ in principle from the method of analysis of an ordinary gas discharge. In the articles mentioned the method used was that of the "three standards", a method widely used, for example, in the spectral analysis of alloys. The essence of this method is as follows: A spectrum of the gas mixture under investigation is produced on a photo plate, together with the spectra of the three standard mixtures (mixtures of known concentrations). The plate is then subjected to photometric analysis, and this data is used to construct a calibration curve, an example of which is shown in Fig. 11 (the relative difference in the blackening ΔS of the lines of the two components under investigation is laid off along the y-axis, and the logarithm of the concentration,

$\log C$, is laid off along the x-axis).

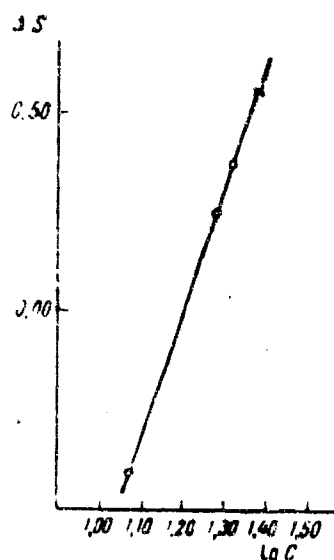


Fig. 11. Calibration curve for determination of the oxygen in the sample

• -- standard mixtures; X -- analyzed mixture.

In accordance with the proposal of S.E. Frish, we used the near infrared region of the spectrum from 7000 to 8000 Å for analysis of the high-altitude samples for oxygen, nitrogen, and argon. We were successful in grouping the intense lines of the indicated elements as follows: OI -- 7772 Å, NI -- 7469 Å, A -- 7504 Å; the exposure and photometric processing presented no difficulties. An ordinary spectrometer with glass prisms (the ISP-51) was used in photographing.

Multicomponent mixtures present the greatest difficulty in the spectral analysis of gases. A change in the concentration of one of the components of the mixture can result in a sharp redistribution of the intensities in the lines of the other components. In each particular case this redistribution may occur in a different way (parallel and nonparallel displacements of the calibration curves). In the next section we will discuss in somewhat greater detail the methods for increasing accuracy in measurements in such cases. Here we will only point out that in our laboratory we succeeded in obtaining an accuracy of 3 to 6% in determination of the content of components.

4. Spectral Microanalysis of Gases

The researcher encounters a number of additional difficulties in the spectral analysis of small volumes of gases which do not arise during the analysis of large volumes of a gas mixture. The smaller the volume of the gas under investigation, the more difficult it will be to achieve a good repetition of the results. Difficulties will be especially great if it is necessary to analyze a gas mixture of less than 1 mm³ in volume (at normal

air pressure). In this case an exceptionally strong influence is exerted on the results of the analysis by the interaction of the excited gas and the walls of the discharge tube. As a result, various parameters of the discharge become unstable.

When employing a high-frequency "electrodeless" discharge in a gas, the result of spectral analysis depends on a number of factors. For the most part these factors can be divided into the three following groups.

A. Factors determining the electron temperature in the discharge: the voltage on the electrodes of the high-frequency generator, gas pressure within the capillary-analyzer, the geometry of the electrodes, the size of the arcing distance, the diameter of the capillary, etc.

B. Factors determining the properties of the inner surface of the capillary: the type of glass used in the capillary, the "prehistory" of the capillary, the volume of mixture analyzed, the glow-time of the discharge, etc.

C. Factors determining the stability of the progress of the photographic and photometric processes: quality of the plate, exposure time, development, photometric processing, etc.

The influence of the last group of factors on the results of the analysis are well known -- this influence is the same in all similar photographic work. The influence of the first two groups, however, has not been definitively clarified.

The dependence of electron temperature on various parameters of a discharge has been studied by many authors, especially by V.A. Fabrikant, who devoted much work to the problem, and by S.E. Frish. We will therefore not discuss them further.

In this Section we will only touch on a number of problems of the influence exerted on a discharge by the second group of factors caused by the interaction of the gas with the material from which the discharge tube is made, since in the process of microanalysis of gases, the factors in this group are the initial source of the stability of the discharge. Sorption phenomena can noticeably change both the density and composition of the gas under investigation, and this can result in a change in the parameters of the discharge, especially in a change in the electron temperature. However, before proceeding to an exposition of the conditions of stability of the discharge, a few words must be said about the method for excitation of the spectrum which we employed in our work.

A small high-voltage generator. A high-voltage generator suitable for the excitation of a discharge in the gas under investigation can be assembled on the basis of a number of well-known circuit diagrams. The circuit diagram and general design of the VG-2 generator, fabricated in the experimental workshops of the Scientific Research Institute of Physics of Leningrad State University, have been described in the literature. We used the VG-2 generator, but its unwieldy size and excessive power, as well as a certain instability in its operation and thermal inertia, forced us to turn to a simpler and more economical model. At our request, Engineer V.I. Makarov designed and built the required generator, one which is far superior to the VG-2 generator in respect to convenience in

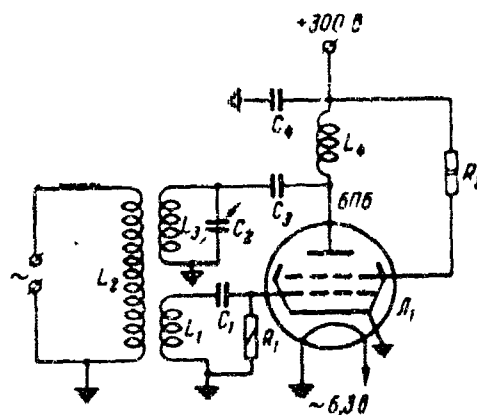


Fig. 12. Circuit diagram for the small generator

R_1 -- MLT 0.5 resistance, 35 k-ohms; R_2 -- MLT2 resistance, 10 k-ohms; C_1 -- capacitor, 40,000 micromicrofarads; C_2 -- capacitor, variable, up to 500 micromikes; C_3 -- capacitor, 1,000 micromikes; C_4 -- capacitor, 50,000 micromikes; L_1 -- 6P6 tube; L_2 -- grid winding, PEL 0.3, 30 turns; L_3 -- output winding, LESH0 7 x 0.07, 1,000 turns; L_4 -- anode winding, LESH0 7 x 0.07, 40 turns; L_5 -- V4 coil, PELSh0 0.2, 120 turns.

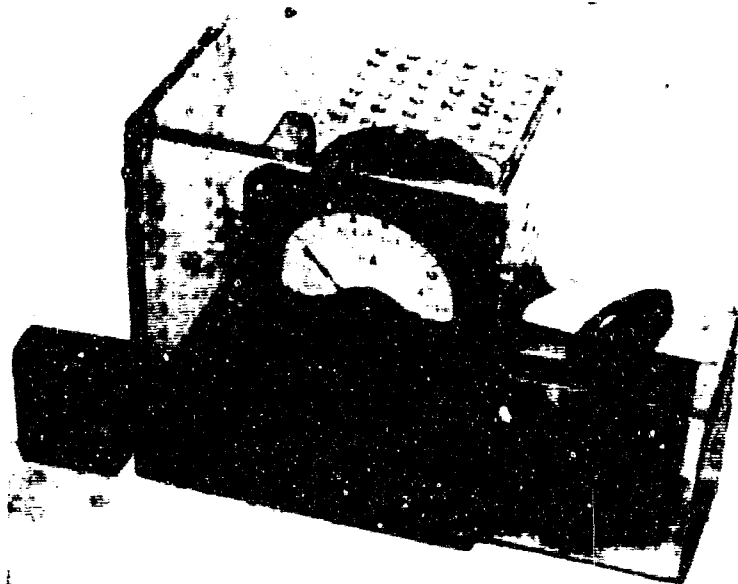


Fig. 13. External appearance of the small generator

handling, size, and operating characteristics. Fig. 12 is a circuit diagram of the generator and Fig. 13 shows its external appearance. This generator differs from the VG-2 generator in its "pocket" size (which can still be considerably smaller) and its electrical characteristics: the discharge current does not exceed 1.5-2 mA, the voltage on the electrodes is of the order of 2500 to 4700 v, and the power of the generator is 1 to 2 watts. The frequency may vary from 0.82 to 0.57 Mc/s, which corresponds to wavelengths of 370 to 530 m. A generator with such an operating regime ensures a good discharge glow and high stability of the results. One notes that with a small current in the arcing distance (1.5 to 2 mA), which is two orders less than the current usually produced during the operation of the VG-2 generator, an excellent excitation of all of the above-mentioned lines of the analyzed air mixture is achieved. At the same time, a reduction of the discharge current considerably decreases the total gas (ion) temperature of the discharge.

Influence of the wall temperature of the discharge capillary. We have already mentioned that the study and evaluation of the influence of the "B" group of factors on the stability of a discharge have made it possible to increase the accuracy of the analysis of the collected gas samples. Since these problems have remained largely untreated in the literature with which we are familiar, we will briefly discuss them here*.

The interaction of a gas with the surrounding surface depends on a number of factors. If it is assumed that the nature of the gas and the surface remain constant, the determining role in such an interaction must be ascribed to the temperature of the wall and the gas coming into contact with it. Sorption and desorption phenomena are dependent on temperature, and temperature also determines the phenomenon of the diffusion of several gases (hydrogen, helium) through the material of which the discharge tube is made (quartz, glass). Therefore, the author, in collaboration with D.A. Mirtova, turned his primary attention to the investigation of the value and time required for stabilization of temperature in the gas--discharge tube system (capillary-analyzer). The investigations were conducted with thermocouples connected with a sensitive galvanometer. The working junction of the thermocouple is clamped to the outer wall of the capillary-analyzer. The capillary itself, together with the thermocouple, is housed in a vacuum jacket. This is done so that convective air currents around the heated capillary will not distort the true temperature of the wall. The temperature of the wall was measured by this method at different places both inside and outside the arcing distance.

Some of the results of the measurements that have been made may be summarized as follows:

- 1) With a prescribed voltage on the electrodes, and in the absence of a discharge in the capillary-analyzer (regardless of whether there is gas within the capillary), neither pure glass nor pure quartz is significantly heated in the generator's high-frequency field. The temperature of the wall begins to increase rapidly, becoming red-hot if the capillary is contaminated on the inside or outside. Particularly harmful is the brownish incrustation on the inner

* A more detailed discussion will be published in special articles.

wall of the capillary which forms during the decomposition of lubricant vapors within the apparatus under the influence of a high temperature in the discharge;

2) The temperature of the wall increases if a discharge is excited within the capillary-analyzer. The temperature of the gas in the discharge, responsible for the temperature of the capillary wall, depends closely on the type of gas within the capillary. This dependence is represented graphically in Fig. 14.

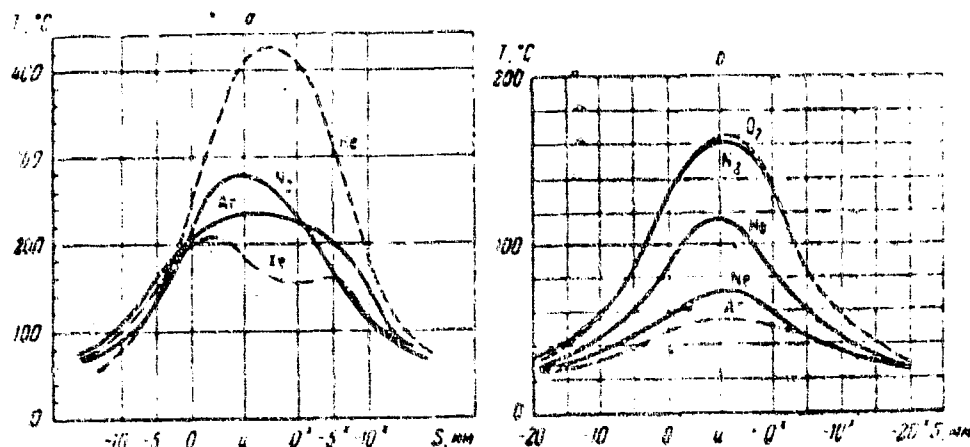


Fig. 14. Temperature distribution along the glass (molybdenum) capillary in the presence of a high-frequency discharge from the VG-2 generator (a) and the small generator (b)

ts -- center of the arcing distance; the zeros on the x-axis correspond to points where there are flat disk-electrodes spaced at a distance of 15 mm from one another; distances are laid off to the right and left of these electrodes; they are situated outside the arcing distance.

The temperature of monatomic gases increases with a decrease in their atomic weights. The "coldest" gas in the discharge is xenon, and the "hottest" gas is helium. The temperatures of diatomic gases (nitrogen, oxygen) differ little from one another, but considerably exceed the temperatures of all monatomic gases*. Fig. 14 also shows the distribution of temperature along the capillary. Its maximum is usually observed in the arcing distance, provided the latter is small. The temperature of the capillary rapidly drops beyond the limits of the arcing distance. The temperature distribution in excited xenon is an exception to this general picture. Here there are two maxima (near the electrodes) and a minimum (at the center of the arcing distance). The same is true for other

* The processes of dissociation transpiring in the discharge apparently play an important role in raising the temperatures of monatomic gases.

gases when there is a very large distance between the electrodes (a distance of about 35 to 45 mm). The source of this phenomenon should be sought in the different heat conductivities of the gases;

3) The temperature of the capillary wall does not immediately attain its maximum value. The temperature of even a thin-walled capillary-analyzer (0.4 mm in diameter) is established (under specified conditions) within 3 to 4 minutes, as can be seen from Fig. 15;

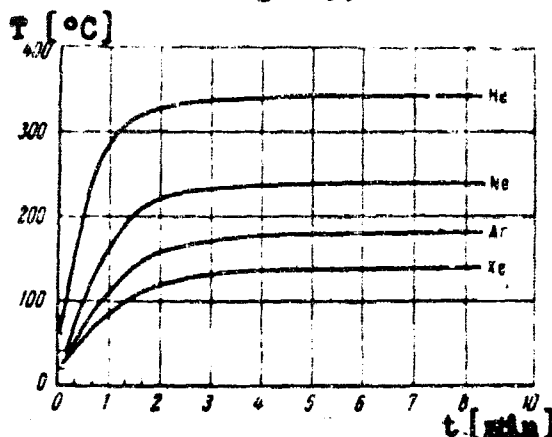


Fig. 15. Time required for establishing a balanced temperature of the walls of a glass (molybdenum) capillary for various gases in the presence of a high-frequency discharge

Temperatures are cited for the center of the arcing distance; the thickness of the capillary wall is 0.5 mm, the diameter of the capillary is 0.4 mm; the time from the moment at which the discharge occurs is laid off along the x-axis.

4) The temperature of the quartz capillary always greatly exceeds the temperature of the glass (molybdenum) capillary when the conditions of the discharge, the geometry of the capillary, and the geometry of the interelectrode distance are maintained;

5) The power of the generator exciting the discharge exercises a considerable influence on the temperature of the capillary wall. A comparison of parts "a" and "b" of Fig. 14 clearly shows that the VG-2 generator, when used under optimum conditions (a discharge glow of the maximum brightness) yields considerably higher temperatures than the small generator which we described above;

6) The geometry of the electrodes and the size (length) of the arcing distance greatly influence the temperature of the wall. The wall temperature increases greatly when broad ribbon electrodes attached directly to the discharge tube are used. The most advantageous electrodes in this respect are disk-shaped electrodes whose inner openings greatly exceed the external diameter of the capillary analyzer. The distance between the disks -- the length of the arcing distance -- should be minimum in order to lower the temperature of the wall.

The comments made above make it possible to select the most advantageous conditions for the analysis of small volumes of gas. The recommendations worked out on the basis of these comments are as follows: 1) Thin-walled capillaries and electrode disks should be used; the latter should not come into contact with the capillary-analyzer and should be placed at a minimum distance from one another (in our case 8 to 10 mm); 2) The spectrum should be photographed after the temperature has evened out (in the case of a thin-walled capillary the temperature evens out in 3 to 4 minutes); 3) It is necessary to use low-output generators to excite the discharge; and 4) the prevalent idea that quartz capillaries have great advantages over glass capillaries when making a microanalysis of gas by the method of a high-frequency discharge must be recognized as being incorrect.

The results of our work point to the absence of such advantages. In the majority of cases, the use of glass is more justified than the use of quartz. When the regime is properly selected, a thin-walled glass (molybdenum) capillary of 0.5 mm in diameter or less can operate for a long time (months) without any noticeable disturbance of the structure of the glass.

Lowering and stabilization of the temperature of the wall of the capillary-analyzer. However well-selected conditions are for the microanalysis of gases within the capillary by the method of a high-frequency discharge, the temperature of the gas and the wall of the capillary remains quite high and instable.

Table 1.

Number of Sample	Difference in ΔS					
	With Ventilation		Without Ventilation		With Variable Ventilation	
	O ₂ - N ₂	A - N ₂	O ₂ - N ₂	A - N ₂	O ₂ - N ₂	A - N ₂
1	-0.24	0.09	0.01	0.05	0.24	0.11
2	-0.28	0.14	0.01	0.04	-0.70	0.11
3	-0.28	0.10	-0.10	0.05	0.75	0.04
4	-0.26	0.11	-0.03	0.04	0.00	0.07
5	-0.26	0.13	-0.02	0.05	-0.39	0.12
6	-0.21	0.10	-0.09	0.08	-0.32	0.17
7	-0.25	0.12	-0.12	0.07	-0.64	0.12
8	-0.28	0.09	-0.08	0.09	0.60	0.09
9	-0.25	0.12	-0.06	0.08	-0.72	0.15
10	-0.25	0.11	-0.03	0.07	0.70	0.12

In order to lower and stabilize the temperature, the author, in collaboration with A.G. Starkova, took measures to cool the glass capillary-analyzer by a jet of cold air at a constant velocity. When this method of cooling was used, the temperature of the outer wall of the capillary, even in the case of the "hot" gases such as oxygen and nitrogen, did not rise more than 10 to 15° in comparison with the temperature of the surrounding medium. This was immediately

reflected on the repetition of the results of the analysis. Table 1 shows the results of photometric measurements of the oxygen (7772 Å), nitrogen (7469 Å), and argon (7504 Å) lines of the spectrum of ordinary air in comparison with the line of nitrogen (7469 Å) taken with constant ventilation, without ventilation, and with variable ventilation by the air jet of the capillary-analyzer. It can be seen that the error in determination of repetition of the ratio O_2/N_2 and A/N_2 in the case of constant ventilation is less than when there is no ventilation of the capillary.

The method of several capillaries. In addition to the temperature of the gas and the walls of the capillary, the "prehistory" of the capillary is of great importance in increasing the stability of the results.

After a prolonged glow discharge in the discharge tube, gas which participated in the discharge remains on its inner surface. This gas is held tenaciously by the walls of the tube and cannot be pumped out. During the subsequent glow of another mixture the sorption gas is liberated in the discharge and can change the analytical results. For the time being measures which have been taken against this harmful phenomenon have not yielded perceptible results. "Washing" of the capillary in a discharge of various gases has by no means always yielded the desired results.

In this connection it appears advantageous, when analyzing air samples taken at great altitudes, to turn to the method of "several capillaries", mention of which has been made above. The essence of this method is that the photographing of the spectra of the standard mixtures is not accomplished in the capillary-analyzer, but in other capillaries identical to the first*. To do this, each standard mixture is held in a special fused container at the pressure required for analysis (for all practical purposes this is 7 to 10 mm Hg). Each container has an outlet which ends with an identical capillary. The gas begins to glow when the outlet capillary is introduced into the generator's arcing distance. By changing the standards in the arcing distance, it is possible to derive the necessary number of control points (most commonly three) for the drawing of a calibration curve. The described method eliminates problems of "prehistory" for standard mixtures.

The use of a capillary-analyzer involves greater problems when it is used for an analysis of the collected sample. The newly annealed glass of the capillary in the discharge actively absorbs gases, especially oxygen. The sample therefore cannot be "ignited" in an untreated capillary. Since there is no way in which we can "wash" the capillary with the mixture which is to be analyzed, it is necessary to "wash" the capillary by a discharge in some gas which is known to be absent from the mixture under investigation. In our case helium is well suited for this purpose. After being treated in this way, the "prehistory" of the capillary-analyzer will be quite simple and standard for all of the analyzed air samples.

* The identical character of capillaries cut from a single piece may be very high. In any case, the analytical errors which may result from a difference in the geometry of the capillaries will be much less than usual errors.

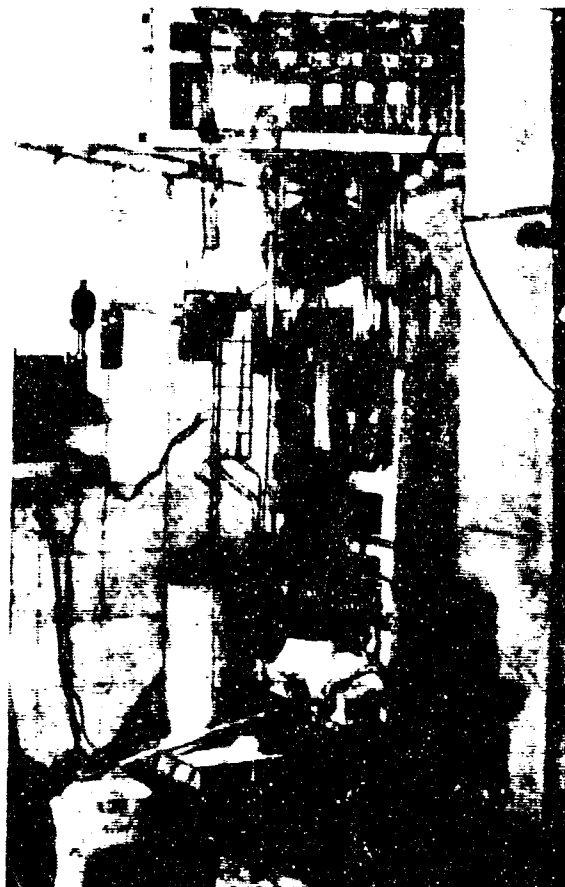


Fig. 16. External appearance of the vacuum pump used in the spectral analysis of samples

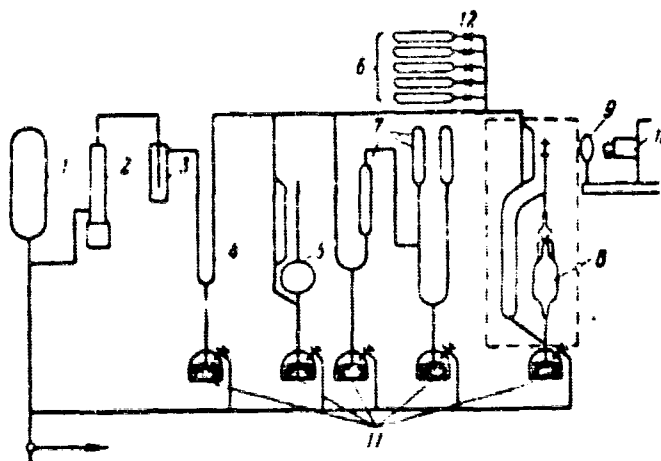


Fig. 17. Circuit diagram of the vacuum pump used for the spectral analysis of samples

1 -- initial vacuum pump; 2 -- high-vacuum Langmuir pump; 3 -- trap used in cooling the liquid nitrogen; 4 -- U-shaped mercury seal; 5 -- McLeod gage; 6 -- set of cylinders with pure gases; 7 -- mixer; 8 -- cylinder with sample, ending with capillary-analyzer; 9 -- spectrograph focusing lens; 10 -- ISP-51 spectrograph; 11 -- shortened mercury lifts; remote control mercury seals for admitting gas into pump.

5. Vacuum Pump

In order to analyze a small sample of air collected at great altitudes, it is necessary that the sample be transferred from the cylinder in which it is contained into a capillary-analyzer and compressed there to a specified pressure. This can be done with the special vacuum pump whose exterior is shown in Fig. 16.

The special requirement of this pump is that its multichannel system should not participate in the transfer of the gas from the cylinder into the capillary; otherwise, the gas in the sample may be partially contaminated and partially lost, undergoing sorption on the extensive surface of the newly annealed glass or remaining behind in various "pockets" of the apparatus. Fig. 17 is a schematic drawing of the pump.

Because of the necessity for making spectral analysis (the method of a single capillary) in the high-vacuum part of the pump, there is a considerable system of cylinders which contain different gases. The special mercury seals shown in Fig. 18 are used to release these gases into the pump. The principle of operation of the seal is as follows. The gas from a cylinder can enter the

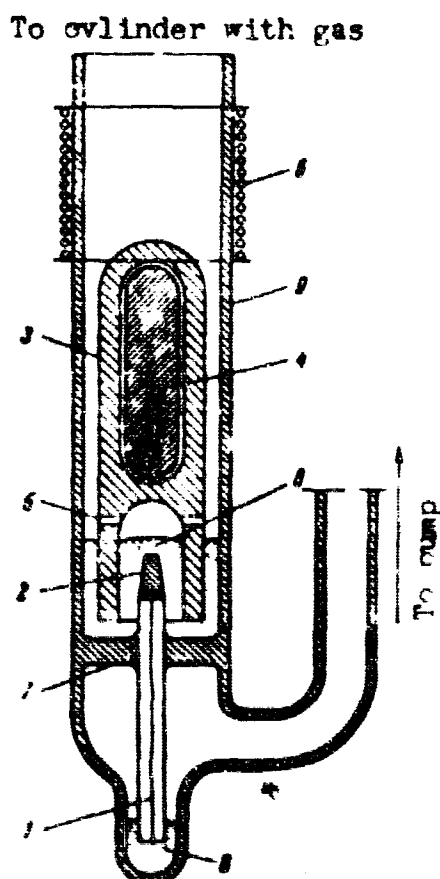


Fig. 18. Remote-control mercury seal for admitting gas into pump

Horizontal: to cylinder with gas; vertical: to pump.

pump only through a narrow capillary 1 which passes through the glass partition 7. The capillary ends with a small piece of porcelain 8. The upper and

lower ends of the capillary are submerged in the mercury 8. The upper end, with the porcelain tip, is situated below the level of the mercury only in a case when the beaker 3 is submerged in the mercury. In order to prevent the beaker from floating in the mercury, a metal core 4 is fused inside it. When the beaker 3 is submerged in the mercury, its level rises above the porcelain and the gas from the cylinder does not pass into the pump. If the beaker rises, the level of the mercury will drop down, exposing the porcelain, and the gas is then able to pass through the pores of the porcelain into the pump, making its way through the drop of mercury in which the lower end of the capillary is submerged. The solenoid 6 is wrapped around the outside of the tube 9. When a current is passed through the solenoid, the steel core of the beaker 3 is drawn into it and opens the seal. When the current is switched off the beaker again drops down and the mercury covers the capillary 1. If air gets into the vacuum pump (by accident), a part of the mercury of the lower drop is automatically forced into the capillary and tightly closes the seal, preventing air from getting into the cylinder with the gas. After evacuation of the pump, the mercury again emerges from the capillary and the seal begins to operate. This latter circumstance makes it possible to open the apparatus easily, which is necessary when connecting the cylinder with the sample to the pump.

The advantage of mercury seals over the usual "batch" seals is beyond question. First of all, there is no vacuum lubricant present, and secondly, it is easy to get the required volume of intaken gases when a mercury seal is used. In addition, these seals operate by remote control, which is very convenient when working with a vacuum pump*.

The apparatus shown in Fig. 17 has a mixer 7 which makes it possible to prepare and store various mixtures. The central part of the apparatus is a capillary-analyzer, accompanied by the cylinder 8 itself, which holds the sample. This part of the apparatus is shown in Fig. 17 by a dashed line and is represented in greater detail in Fig. 19**.

As was mentioned before, the small volume of gas enclosed in the cylinder cannot be introduced into a multichannel system. Therefore the interconnection of the tubes, as shown in Fig. 19, is designed in such a way that with the use of mercury it is possible for the gas from the cylinder to be transferred directly into the capillary-analyzer, bypassing all auxiliary channels. This is done by fusing the cylinder into the vacuum pump with the thin glass tubes remaining intact, as shown in Fig. 19. The apparatus is then carefully evacuated and degasified, since until this time the apparatus was open. Before the evacuation is completed the mercury rises to the level A (Fig. 19) and the lower tubular glass extension is knocked off with a special hammer. Mercury fills the cylinder, forcing the sample of gas to the upper tubular extension. The latter is broken off when the mercury rises to the level B.

* Our work over many years with mercury seals has confirmed their great superiority over seals of other types.

** Since the overwhelming majority of the samples were investigated in precisely this way, i.e., the entire cylinder was fused in the apparatus, and not the storing capillary alone, we shall describe this method, especially since the same system is used during the transfer of the gas from the cylinder to the storing capillary (See Fig. 17).

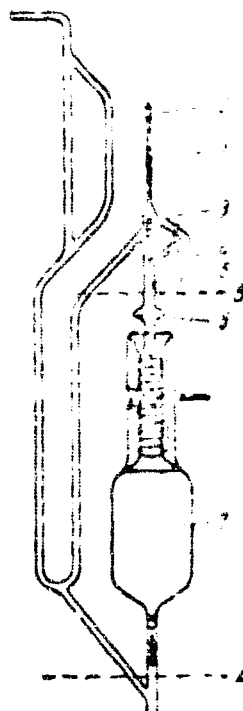


Fig. 19. Cylinder and capillary-analyzer

1 -- capillary-analyzer; 2 -- arcing distance;
 3 -- hammer for breaking off glass extension;
 4 -- catch for hammer; 5 -- glass extension;
 6 -- plug for cylinder seal; 7 -- cylinder;
 A -- level to which mercury rises when lower
 glass extension is broken off; B -- mercury
 level when upper glass extension is broken
 off.

Further pressure introduces all of the gas directly into the capillary-analyzer*.

The method of forcing out the gas by mercury is inconvenient when it is necessary to force the gas from large-capacity glass cylinders. The filling of a thin-walled 3-liter glass cylinder with mercury presents the danger that

* Other methods for transferring the gas into the capillary, such as pumping, usually lead to distortion of the composition of the gas or to losses of gas in "pockets" in the pump.

the cylinder will be ruptured. This can be prevented in the following manner*. The cylinder containing the gas sample is fused into the apparatus in the usual manner (See Fig. 19). The cylinder is then surrounded by a cardboard or tin housing which exceeds by 2 or 3 cm the diameter of the cylinder. The housing rests freely on a supporting base which is situated beneath the cylinder. The free space between the walls of the housing and the cylinder are filled with a liquid solution of alabaster or plaster of Paris. After the solution has dried, the cylinder is protected by an ideal protective shell (Fig. 20) and can be freely filled with mercury without any risk. A vacuum pump with such a cylinder is shown in Fig. 20.

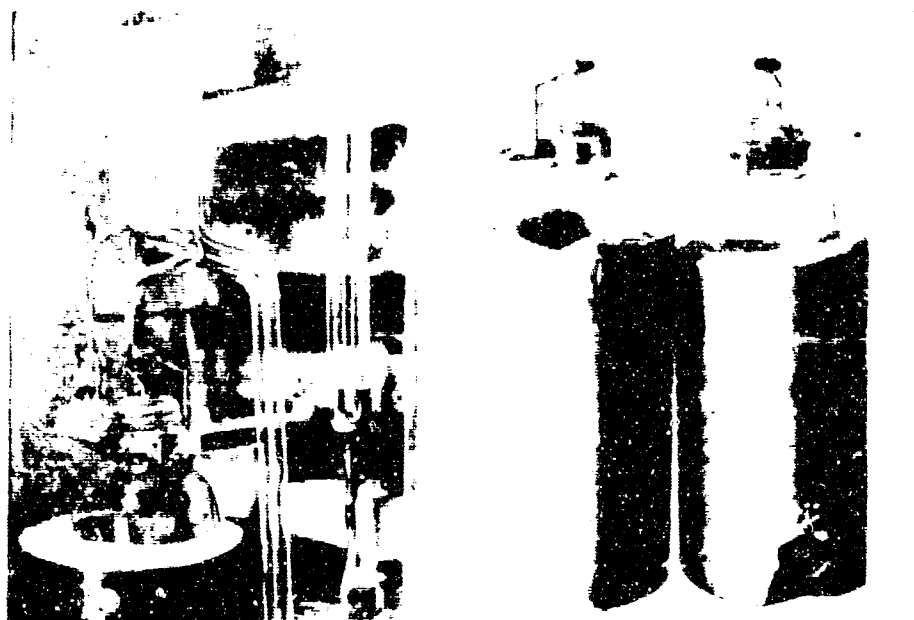


Fig. 20. Analytical apparatus with cylinder fused in

The photograph at right shows glass (thin-walled) cylinders encased in plaster of Paris.

When all of the gas is forced from the cylinder, and the level of the mercury is situated above the level B (Fig. 19), the hammer 3 is closed. The gas must be subjected to intense cooling action in order to be freed (insofar as possible) of the water vapor, carbon dioxide, and carbon monoxide which may be present in the apparatus. Ordinary cooled traps are in this case unsuitable because when they are used there is a great loss of the gas under investigation. We therefore made a trap of the "passageway" type which did not form a "pocket" in which a loss of gas could occur. The trap is shown in Fig. 21. Its principal component is a glass tube with double walls separated by an excellent vacuum. The tube is open at both ends. It is fused within an ordinary glass tube which is part of the pump lines situated immediately in front of the inlet to the capillary-analyzer (See Fig. 19). A Dewar flask is fused to this external tube for the

* The method was proposed by A. A. Baykov.

liquid nitrogen which cools the walls of the tube. The highly cooled walls of the outer tube constitute a "trap" where condensed gases undergo sorption. The following would occur if an internal Dewar flask were absent: When the "frozen" gas was forced into the capillary, the mercury would rapidly freeze on coming into contact with the cold external walls; a solid "plug" would thus be formed, which would block the entrance of mercury into the capillary-analyzer. It is a different matter when the Dewar flask is placed inside.

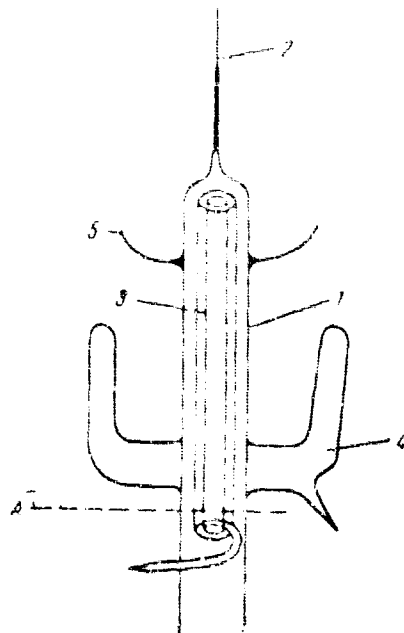


Fig. 21. Trap of the "passageway" type. Diagram of the trap

A -- level to which the mercury rises before the gas is cooled; 1 -- outer tube; 2 -- capillary-analyzer; 3 -- inner Dewar flask within which the mercury can pass without obstruction during the freezing of the walls of the tube 1; 4 -- outer Dewar flask for cooling of the tube 1; 5 -- glass shield protecting the upper end of the tube 1 from the cold vapors of liquid nitrogen.

In this case, the plug of freezing mercury will only form in the space between the outer wall of the Dewar tube and the frozen wall of the pump line. The passageway within the Dewar tube does not freeze at all and remains open for the passage of the mercury. On rising along this line, the mercury emerges through the upper opening of the tube and fills the entire space of the trap. Leaving behind the frozen plug, the mercury enters into the capillary-analyzer, there collecting all the gas which is subject to "freezing." When the required pressure is reached in the capillary, high voltage is fed to the electrodes which surround the capillary, and the gas enclosed in the capillary

begins to glow. A spectrograph is used to photograph the spectrum of this glow and an analysis of the gas sample is made on the basis of this spectrum.

6. Results of the Experiments

Much work was carried out by us in the collection of air samples from great altitudes during the period 1951 to 1957. We analyzed these samples in collaboration with O.P. Bochkova. The methods described in this report were used in sampling and analysis. Not all of the experiments were successful. Table 2 therefore gives only the results of those analyses for which we have no reservations as to the purity of the experiment. The samples were taken in the middle latitudes of the European part of the USSR, primarily in the spring and summer in the morning hours (local time).

The data in Table 2 make it possible to conclude that 1) up to an altitude of 95 km there is no appreciable separation between oxygen and nitrogen; and 2) the volume of the heaviest gas, argon, is less at heights of 85 to 95 km than at the earth's surface.

Table 2.

H, km	Pressure within the Cylinder, mm of Hg	Composition of Sample, % by Volume			H, km	Pressure within the Cylinder, mm of Hg	Composition of Sample, % by Volume		
		O ₂	N ₂	A			O ₂	N ₂	A
65	$1.7 \cdot 10^{-3}$	19.0	80	0.94	82-85	$4 \cdot 10^{-3}$	24.5	74	0.77
75-80	$2.0 \cdot 10^{-3}$	21.0	78	0.93	82-85	$3.7 \cdot 10^{-3}$	20.5	78	0.79
75-80	$2.5 \cdot 10^{-3}$	21.0	78	0.93	82-85	$4.4 \cdot 10^{-3}$	19.0	80	0.91
80	$1.1 \cdot 10^{-3}$	21.5	78	Slight	85	$3.7 \cdot 10^{-3}$	21.0	78	0.86
80	$1.0 \cdot 10^{-3}$	19.0	80	0.86	85	$3.2 \cdot 10^{-3}$	21.0	78	0.90
80	$1.5 \cdot 10^{-3}$	22.0	77	0.87	85	$3.4 \cdot 10^{-3}$	21.0	78	0.88
80	$8.0 \cdot 10^{-3}$	23.0	76	0.90	95	$1.2 \cdot 10^{-3}$	21.5	77	0.76

The decrease in argon with increasing height is still relatively small, but nevertheless it can be concluded that there is diffuse separation at altitudes of the order of 100 km.

Recent data on the composition of the upper layers of the atmosphere give us a less fragmentary picture than we had only three years ago. True, there still remain certain disparities between theory and experimental data, but these relate to individual experimental results, especially results obtained by means of radiofrequency mass spectrometers. Recent work gives data which are in good agreement. At the same time a careful critical analysis of previous work has revealed defects which have led to contradictions in their results and which have made it impossible to accept them at face value.

The very essence of the method of taking samples has recently been subjected to question in a number of articles. It therefore seems necessary that we examine in detail the objections and apprehensions expressed.

For example, in an article by Ye.G. Shvidkovskiy, it is correctly pointed out that, generally speaking, when employing the method of sampling, the proper interpretation of the results requires a precise knowledge of the angle between the velocity vector of the rocket's (capsule's) trajectory and the axis of the inlet of the cylinder at the moment of sampling. It is very difficult to determine this angle of incidence. However, to a great extent this difficulty has been avoided through the particular manner in which our measurements were made in the capsule. The measurements were facilitated by the low velocity of the capsule at the moment the sample was taken -- an order less than the mean thermal velocity of molecules (peak of the trajectory) -- and the positioning of the cylinders within the unhoused part of the capsule. The cylinders were attached in such a way that their inlets did not fall directly in the flow.

The essence of the objections advanced by Martin is that the gravitational separation discovered by Paneth is the result of distortions of the composition resulting from measurements on the rocket. In particular, the presence of a long inlet in the cylinder (25 cm) can lead to the forced separation of gases entering into the cylinder under the Knudsen regime. It is also pointed out that the great velocities of the rocket (several times greater than the velocity of sound at the time of the sampling), result in a disparity between internal pressure in the cylinder and external pressure, and increase the possibility of forced separation, thereby creating a regime of nonstationary flow.

The computations made by Martin, which take into consideration the specific elements involved in the experiment (capacity of the cylinder, diameter of the inlet mouth, length of the inlet itself, velocity of the rocket, moment of sampling, etc.), seemingly confirm his assumption that there is a forced separation of gases at the moment the sample is taken. However, our experiments have not confirmed Martin's assumption as to the forced separation of gases. In fact, all of the specific elements of our experiment differed completely from the specific elements of the American work. First, our low-capacity tanks have virtually no inlets (the length of the passage in the seal does not exceed 1 cm). Second, the velocities at which the samples were taken do not exceed 50 m/sec (peak of trajectory)*. The pressures inside and outside the cylinder are therefore well matched, and this is evidence of a balanced process of establishing pressure in the cylinder. Third, our measurements, made on an easily ventilated small capsule ejected from a rocket, differ substantially in aerodynamic conditions from the American work on the rocket itself. Thus, the ideas of Martin, which he expressed in respect to the American work, are scarcely applicable to the description of the physical processes transpiring during the taking of samples in our experiments, and the results of our work are in good agreement

* It is superfluous to mention here the advantages of a capsule over a rocket. In making an experiment with a rocket the researcher must invariably work at high velocities in order that the associated cloud of hostile gases be blown away. There is no need of this for a capsule not accompanied by such gases.

with the work of E.A. Wenzel. Fig. 22 is a graph used for illustrating this point (the graph was taken from the work of E.A. Wenzel). This graph shows a comparison of data from the American work in determining the gravitational separation of the nitrogen and argon gases by the sampling method (black dots) and the radio-frequency mass-spectrometer method (open circles) with our data (squares). The coefficient of separation r is laid off along the x-axis on the graph (if $r = 1$, separation is absent), and altitude is laid off along the y-axis.

If we take into account the fact that the time and place for taking our samples and the American samples (low, high, and middle latitudes) are very different from one another, the agreement in the results must be considered good. It seems extremely improbable that the results of the analyses made in our country and abroad would coincide accidentally. The probability of such coincidence becomes even less if we take into account the fact that the indicated experiments differ not only in the method of sampling, but also in the method of analysis itself. It should rather be assumed that the experimental data derived in our country and abroad, which confirm the presence of the gravitational separation of nitrogen and argon gases at altitudes of the order of 100 km, are quite objective.

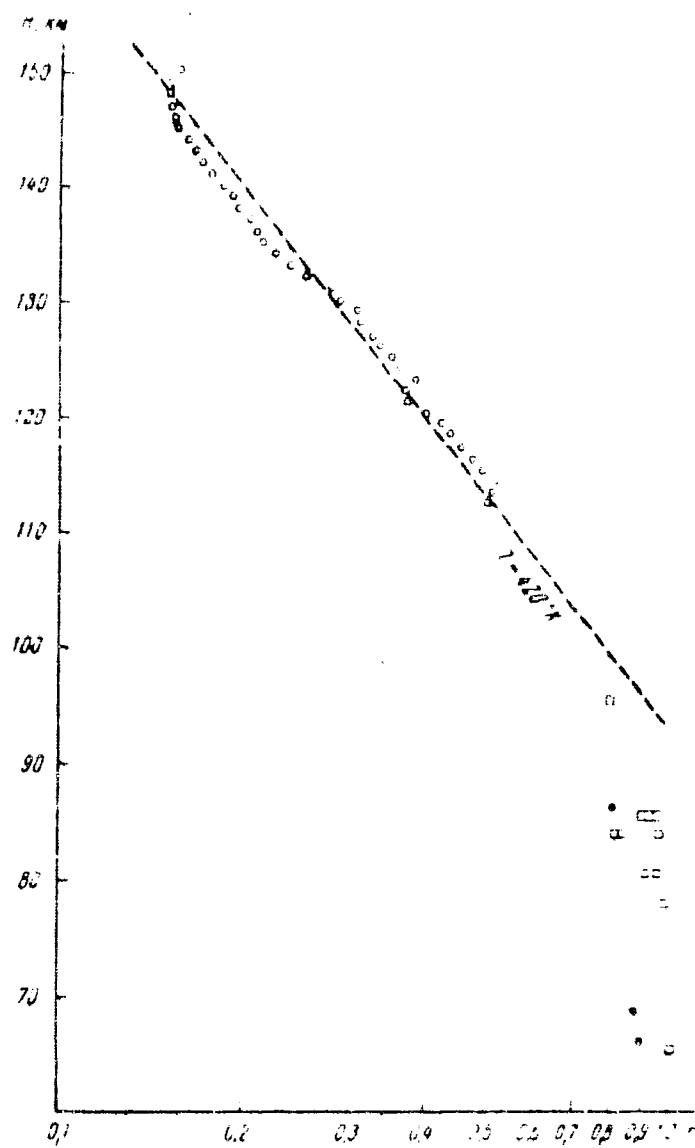


Fig. 22. Gravitational separation of the nitrogen and argon gases.

Soviet 1

Station	Leader	D a t e		Duration (days)	C o Beginning
		Beginning	End		
Severnnyi Polius-1	I.D. Papanin	21.3.1957	19.8.1958	274	89 25'N. 70
Severnnyi Polius-2	M.M. Semov	2.4.1958	11.4.1959	374	76 03'N. 166
Severnnyi Polius-3	A.F. Troshnikov	9.4.1958	20.4.1959	376	85 58'N. 178
Severnnyi Polius-4	E.I. Tolstikov	3.4.1958	27.4.1959	374	75 40'N. 178
	P.A. Gordienko	27.4.1959	18.4.1960	367	80 49'N. 175
	A.G. Braikin	18.4.1960	10.4.1961	367	87 24'N. 177
				1,108	
Severnnyi Polius-5	N.A. Volkov	21.4.1958	20.4.1959	366	82 10'N. 156
	A.I.A. Sokolov	20.4.1959	3.10.1959	221	85 10'N. 183
				587	
Severnnyi Polius-6	K.A. Sychev	14.4.1958	19.4.1959	355	74 24'N. 177
	V.M. Brilatskiy	19.4.1959	8.4.1958	354	75 50'N. 171
	S.T. Serdyukov	4.4.1958	12.4.1959	370	80 55'N. 150
	V.S. Antokhin	12.4.1959	11.4.1959	156	8 18'N. 39
				1,24	
Severnnyi Polius-7	V.A. Vedernikov	22.4.1958	11.4.1958	355	82 06'N. 164
	N.A. Dolov	11.4.1959	11.4.1959	366	86 21'N. 149
				721	
Severnnyi Polius-8	V.M. Rogov	27.4.1958	13.4.1960	342	76 11'N. 164
	N.A. Bilenov	13.4.1960	1.6.1960	-	79 09'N. 179
Severnnyi Polius-9	V.A. ...	26.4.1960	2.5.1960	-	77 14'N. 165
Severnnyi Polius-10					
Severnnyi Polius-11	N. N. Bryukov		4.1962		
	(replacing SP-3)		U.S.S.R. 4.1962)		

Copyright

Plotting Stations

Coordinates			Length of drift (km)		Speed of drift (km/day)	
E n d			Actual	In general direction	Actual	In for direction
40'W.	70 40'W.	29 16'W.	2,050	1,750	7.50	6.40
36'W.	81 44'W.	263 48'W.	2,600	640	6.90	1.70
00'W.	86 00'W.	24 00'W.	1,863	825	4.90	2.20
25'W.	80 49'W.	275 35'W.	2,532	585	6.80	1.60
35'W.	87 24'W.	277 46'W.	2,500	770	6.81	2.10
46'W.	85 52'W.	00 00 W.	2,937	755	5.27	2.10
			6,980	2,211	6.30	1.90
51'E.	86 18'W.	00 57'E.	2,580	800	6.90	2.20
57'E.	84 18'W.	63 20'E.	2,510	200	6.40	1.60
			2,610	1,000	6.70	2.00
04'W.	75 50'W.	270 40'W.	2,500	1,360	7.10	2.00
45'E.	80 50'W.	270 40'W.	2,500	700	7.23	2.70
15'E.	86 22'W.	39 37	2,500	1,220	6.80	3.30
37'E.	82 00'W.	56	2,565	1,000	6.80	3.80
			8,000	2,000	6.00	2.30
22'W.	86 21 N	149 38 W	2,920	480	6.10	1.20
30'W.	85 24 N	120 35 W	2,600	790	6.40	2.20
			3,520	1,240	6.80	2.70
24'W.	79 09'W.	270 35'W.	2,590	374	7.30	2.70
35'W.?	81 07'W.	277 30'W.	-	-	-	-
43'W.	79 52'W.	150 30'W.	-	-	-	-

SUBJECT: AID Work Assignment No. 32. (National Weather Service, USSR),
Report 1 ~~Part 1~~.

SOURCE: Baigis, I., and S. Schneider. Aerologiya v Arktike. Morskoy Flot,
no. 12, 1961, 39.

List of Aerological Stations in the Meteorological Network Under Glavsevmorputi (Main Administration of the Northern Sea Route)

- | | |
|---|--|
| <p>A. Svalbard
1. Ruessbukt
B. Franz Josef Land
2. Ostrov Zhays (Zhays Island)
C. Novaya Zemlya
3. Mys Zholaniya
4. Mys Kuznetsov
D. Kara Sea, Islands, Coasts, and
Adjoining Continental Areas
5. Ostrov Vise
6. Ostrov Bol'y
7. Ardeana
8. Mys Kameny
9. Ostrov Bihon
10. Ostrov Ushakov
11. Dufina
12. Igarka
E. Laptev Sea (Laptev Sea)
13. Mys Chapurkina
14. Eksterna
15. Ostrov Prokhorovskiy
16. Bunka Tikhaya
17. Ostrov Kotel'yy</p> | <p>F. East Siberian Sea
18. Mys Shal'neva
19. Chukotka
20. Ostrov Zhukova
21. Nishniye Krasty
22. Ostrov Chetyrehstolbovoy
23. Ostrov Ayon
24. Ostrov Vrangeliya
[Wrangle Island]
25. Mys Shmidt
G. Bering Strait, Bering Sea
26. Udon
27. Bunka provizionnaya
28. Bunka Ngol'naya
H. Central Arctic Basin
"North Pole" Stations
29. "Severnnyy polus"
(~85°30' N, 72°00' E)
30. "Severnnyy polus"
(~73° N, 172° W)</p> |
|---|--|

SUBJECT: AID Work Assignment No. 32 (National Weather Service, USSR), Report 1.

SOURCES: Indicated below.

- 1) Obukhov, A.M., and A.M. Yaglom. On the microstructure of atmospheric turbulence; review of recent work in the USSR. IN: Royal Meteorological Society. Quarterly Journal, v. 85, no. 364, Apr 1959.

In the USSR, a number of theoretical and experimental investigations concerning the microstructure of the principal meteorological fields -- mainly, those of wind velocity and temperature -- have recently been carried out. Some special problems of the physics of the atmosphere have also been studied using the results of the first investigations.

- 2) Il'in, I.A. Hydrometeorological study of mountainous regions. Meteorologiya i gidrologiya, no. 2, 1962, 46-47.

Hydrometeorological service in mountainous areas of the USSR is considered completely inadequate for collecting data on snow accumulations in watersheds, precipitation, and runoff. These data are needed for making hydrological computations and forecasts. The only feasible means to improve operations appears to be an increase in personnel at already established stations and an improvement in the program of observations. Most stations make little effort to make observations away from their immediate vicinity. Many meteorological stations of the Kirgiz and Tadzhik SSR's make no attempt to study the rivers and lakes on which they are situated or nearby glaciers. Also they are often ignorant of the meteorological conditions in nearby areas. Many stations are in fact badly placed and their data are atypical for the area.

A series of eight measures is recommended for improving the service: 1) standard observations at all stations; 2) study of all rivers and water bodies; 3) careful selection of station sites at points where runoff studies can be made; 4) snow cover study by all stations on traverses 10 to 20 km long; 5) measurement of precipitation over more extensive areas in the vicinity of stations; 6) precipitation measurements near observers' dwellings; 7) study of nearby glaciers; and 8) selection of site and observation program to be by a professional commission.

- 3) Taradankin, A. Friend of the Polar specialist. Sovetskaya Rossiya, 10 Nov 1961, 4.

Scientists aboard the nuclear-powered *Lenin* operating in the Chukchi Sea have set up automatic meteorological stations. The

first such unit was established at the CH-10 drifting station. By 9 or 10 Nov, 10 stations had [apparently] been established.

The radio buoys and automatic stations facilitate the determination of ice flow force and direction and transmit data on temperature and wind velocity and direction. Antennas for the stations are about 12 meters long.

- 4) Burkova, M.V. On westerly cyclones over Soviet Central Asia. IN: Sredneaziatskiy nauchno-issledovatel'skiy gidrometeorologicheskiy institut. Trudy, no. 4 (19), 1961, 10-12.

Westerly cyclones, differing from the region's three generally accepted cyclone types (the South Caspian, the Murgabian, and the Upper Amu Dar'yarian), have been studied and assigned a separate category in the regional climatology of Soviet Central Asia. The westerly cyclones differ from the South Caspian in the nature of the macrosynoptic situation that precedes the cyclone breakout and in the position of the planetary upper-level frontal zone. They originate in a broadly orientated planetary upper-level frontal zone, pass over the Mediterranean, and travel in the direction of the Black Sea and Soviet Central Asia. The westerly cyclones are almost entirely occluded and do not cause any noticeable warming, but do bring considerable precipitation 1) in the occluded front area and 2) to the rear of the cyclone. They cause strong winds on the Aral Sea and in the Kara Kalpak. Owing to their regular movement along almost straight isohypsal lines, the westerly cyclones are easy to forecast.

- 5) Dubov, A.S. All-Union scientific meteorological conference marking the 40th year of the Soviet Hydrometeorological Service. IN: Akademiya nauk SSSR. Izvestiya. Seriya geofizicheskaya, no. 1, Jan 1962, 138-141.

... P.K. Yevseyev discussed the modern computer techniques employed in the State Hydrometeorological Service and the prospective use of automation in processing observations. Among the important steps, he noted the organization of a joint meteorological computation center and the preparation of a centralized computer--telemetering center for processing aerological data.

... In the section of the physics of the free atmosphere (chairmen V.Ya. Nikandrov, N.Z. Pinus, and A.Kh. Khriyan), 47 reports were given on the physics of clouds, active modification of clouds, radar investigations, atmospheric electricity, chemistry of clouds, and physics of the upper layers of the atmosphere. The resolutions of the section commended the successful experimental work in creating new approaches for direct investigation of the upper layers of the atmosphere and the electrical and other characteristics of clouds. The basic problem of future investigation will be to

satisfy the demands of the national economy for aerological data on high altitudes, the expansion of the application and experimental development of the active modification of clouds, and the study of atmospheric turbulence.

6) Newsweek, 5 Feb 1962, 52.

"Dr. Donald Gilman, a research meteorologist with the United States Weather Bureau, is reported to have given an evaluation of Soviet long-range weather forecasting at a meeting of the American Meteorological Society in New York. In his comparative evaluation of performance, using 100 as a standard, he rated Western forecasters in the 20 to 30 bracket and Soviet forecasters at -2.

"Despite the Russians' poor showing, he continued, the forecasting method they used is most promising. It is called the 'dynamic model' system in which a mathematical model of the weather is drawn up using the classical laws of hydrodynamics and thermodynamics and the current weather readings. 'You simply run the data through a computer,' Gilman said, 'and stop at anything from a 24-hour to a seasonal projection. We use this method for the five-day forecasts, but we think that's the limit of its reliability. The Soviets made a brave attempt to carry it all the way out to monthly and seasonal forecasts.' Next year, however, the Russians may be doing as well as everyone else, for they have apparently decided that they were pushing their mathematical technique too far. Now they have abandoned it for the more reliable 'empirical' method.

"Empirical forecasts are made largely by comparing current readings with past records. The system is safer, Dr. Gilman noted, 'but potentially not as powerful as the dynamic model, which could change forecasting from an art to a physical science.'"

7) Seregina, V. Vechernyaya Moskva, 5 Feb 1962.

The 5 Feb 1962 issue of Vechernyaya Moskva carries a report by V. Seregina, scientific worker at the Central Institute of Weather Forecasts, on weather conditions prevailing in different parts of the world during the preceding week. The report indicated that the weather throughout Europe during the first part of the week had been quite cold, with temperatures ranging from -27 to -32°C in Norway, Sweden, and Finland. The cold wave had penetrated as far south as the Mediterranean, with snow in Italy and such unusually low temperatures as -1 to -4°C in Corsica, Sardinia, the Appenine peninsula, and southern France. Even in Tunisia and Algeria, where winters are generally warm, the snow was 70 cm deep in some places.

Toward the end of the week, there was an overall increase in temperature, increased cloudiness, and high winds [described in

detail] throughout Europe. In the North Atlantic and along the coast of Canada and the United States very cool and windy weather prevailed. During this period, the weather in India, Indonesia, and Central Africa remained seasonably hot with temperatures ranging between 30 and 40°C, and the sun shining brightly.

COMMENT:

Such weather reports as that just described are becoming a common feature in the Soviet press. They apparently provide a check of the reliability of worldwide forecasts being made by Soviet meteorologists in the course of integrated and synoptic weather studies. As far as is known, these reports are not published elsewhere.

- 8) Goshko, I.I. Meteorological advice to military pilots. Vestnik vozdushnogo flota, no. 1, 1960, 48.

At Soviet Air Force bases there is always a meteorologist on duty ready to give advice about meteorological conditions during the training flights. When flying under complicated meteorological conditions, the pilot especially needs information on the character of the cloudiness, upper and lower boundaries of clouds, etc. A knowledge of these data will help the pilot to make a proper selection of the flight profile and to take necessary precautions. Soviet military flying personnel are constantly studying meteorology. The knowledge they obtain in the classroom is supplemented by practical training. Experienced meteorologists, in regular consultations with pilots, analyze synoptic conditions and thoroughly explain weather maps.

- 9) Zhukovskiy, V.V. Meteorological training of air force pilots. Vestnik vozdushnogo flota, no. 2, 1960, 60.

Experience has shown that pilots who have had proper theoretical instruction in meteorology can master the analysis of synoptic maps and can learn to compile short-range weather forecasts. Therefore, flight crews are required to attend classes in meteorology, where at first they study a general program and the climatic peculiarities of the flight region. They advance to a meteorological service group, where in the first phase they learn to read the symbols of weather maps fluently, to trace isobars, and to determine air masses and discern frontal boundaries. In short, they learn to process and analyze general weather maps. The second phase involves the rough processing and analysis of a regional synoptic dense-network map, participation in the analysis of the total synoptic material, and finally, at the end of the workday, the compiling of a weather forecast for the next 24 hours.

In addition, the pilots must learn the symbols of the synoptic code used on weather maps, assist the meteorologist on duty in drawing up synoptic charts, and finally, make short-range weather forecasts on their own.

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Report 1. Paragraph 3. *L*

SOURCE: Borovikov, A. M., I. I. Gayvoronskiy, Ye. G. Zak,
V. V. Kostarev, I. P. Mazin, V. Ye. Minervin, A. Kh. Khrgian,
and S. M. Shmeter. Fizika oblakov (Physics of clouds).
Leningrad, Gidrometeoizdat, 1961. 458 p.

ABSTRACTS: *Artificial* Artificial Activation of Clouds and Fogs

The Advantages of Solid Carbon Dioxide
[pp. 338-339]

Solid carbon dioxide is cheap, simple to use, and effective. One kg of carbon dioxide produces the same results as 25 kg of silver iodide or 400 kg of water in the liquid phase. In order to predict the effect of a reagent and to estimate how much of it should be used, it is necessary to know its effective quantitative characteristics under different meteorological conditions. The basic processes taking place when solid carbon dioxide is used were investigated in the USSR by Nikandrov, Krutskaya, Solov'yev, Shefer, and Gayvoronskiy.

The Effect of Carbon Dioxide on the Phase Transformation of Clouds and Fog
[pp. 339-340]

Studies have shown that the effect of carbon dioxide on the phase transformation of clouds and fog is purely thermal. Experiments conducted at the Central Aerological Observatory showed that when carbon dioxide was introduced into a closed cooling chamber 8 m³ filled with fog, where the prevailing temperature was -10°C, the same crystallization process took place as under open air conditions. Furthermore, kerosene, benzine, ether, desalinated ice, and other substances precooled to -60 to -70°C and introduced into the chamber also induced intense crystallization of the fog. This disproves the belief held earlier that the introduction of dry ice into clouds is accompanied by the formation of chemically active nuclei.

Use of Solid Carbon Dioxide
[pp. 352-353]

There are 2 methods for the aerial injection of solid carbon dioxide (CO_2) into clouds: 1) by evaporating carbon dioxide directly from the plane while flying through a cloud or fog, and 2) by seeding granulated solid carbon dioxide while flying over the cloud's upper boundary. A granule of solid CO_2 1 cm in diameter will fall approximately 4.3 cm before evaporating. Thus, smaller granules may be used in seeding clouds of relatively small vertical thickness. According to the Central Aerological Observatory, granules less than 0.3 to 0.5 cm in diameter do not induce the required effect due to considerable evaporation before reaching the cloud. It is most important that seeding be continuous and uninterrupted. If seeding is "focal", a total dispersion may not be achieved.

The rate at which CO_2 is fed is of considerable importance. In the process of seeding, clouds or fog are totally transformed from the droplet to the crystalline phase. A very large number of the small crystals formed do not reach the size of snow flakes because of the lack of moisture, and remain in a state of suspension. V. Ya. Nikandrov developed a theoretical basis for computing the amount of solid CO_2 to be fed in activating supercooled clouds, and I. I. Gayvoronskiy established experimentally the optimum dosage for dispersing supercooled clouds and fog.

The dosage depends on the prevailing temperature. In dispersing fog at -5°C and at -15°C , the outlay of carbon dioxide is 100 g and 30 g respectively per 1 km traversed. The dispersion of clouds requires a greater expenditure, because clouds contain a greater amount of water. Usually, 5 min after seeding, snowfall is observed, and after 35 to 50 min, depending on the vertical thickness of the cloud, the cloud is completely dispersed in the area of activation. The average width of the zone of dispersion in one run of the airplane is 3 to 5 km. An increase in the dosage of CO_2 increases the width of the dispersion zone only up to a point. The rate of propagation in the dispersion zone both in clouds and fogs is on the average approximately 2m/sec. At low temperatures, this rate is slightly higher. The upper temperature threshold of the effective application of solid carbon dioxide is between -3 to -4°C . The lower margin is determined by the amount of water drops in the cloud or fog.

Studies conducted by the Central Aerological Observatory indicate that clouds of mixed structure may be dispersed with small quantities of CO_2 . Fogs of mixed structure, particularly radiation fogs, are very rare. In such cases, CO_2 is seeded either from an airplane or from the ground.

Aerial CO₂ Equipment

[pp. 353-356]

In 1957 an automatic dosimeter unit, which granulates and disseminates specified amounts of CO₂, was designed for use on a plane. Its most important parts are 1) a granulating mechanism which produces granules 0.5 to 1.0 cm in diameter from solid or snowlike CO₂, 2) a dosimeter which meters out between 100 and 3000 g of CO₂ per minute, 3) a control panel for starting, stopping, and controlling all operations, 4) a container for storing solid or snowlike CO₂, and 5) a clamping device for holding the CO₂ block during the granulation process. The various mechanisms are operated by an electric motor fed by the plane's electric system.

Ground CO₂ Equipment

[pp. 356-358]

Studies conducted by the Central Aerological Observatory show that when CO₂ is evaporated from the plane into the lower part of a cloud, the crystallization proceeds intensely from the bottom upward. A zone of dispersion is eventually formed which is as large as the zone of dispersion which forms when the CO₂ is introduced into the upper part of the cloud.

With the use of this method, a cloud 300-400 m in vertical thickness was successfully dispersed. The ground equipment constructed in 1954 for this purpose has the following operating parts: 1) a cylinder containing liquid CO₂, 2) a metering device for feeding CO₂ into the fog at the rate of 25 to 50 g/km, 3) a ventilator with a guide funnel, 4) a motor for rotating the ventilator, 5) a control panel, and 6) an enclosed operator's cabin. The entire unit is fixed to a sled which can be easily moved from place to place by a tractor during the operation. The cylinders are equipped with overflow valves. The liquid CO₂ flows from the cylinder into the collector, then along a tube toward the exit valves into the metering device, and subsequently, into the diffuser where it expands quickly and is transformed from the liquid into the solid (snowflake) phase. A stream of air from the ventilator breaks up the CO₂ into small pieces which rise to a height of 10 to 12 m. The unit is also equipped to use dry ice. Experiments show that such a unit operating from the ground may be used to disperse supercooled clouds over an area of several tens of kilometers square. A slightly different unit was developed at the same time in which the carbon dioxide was released under

pressure from the cylinder into the atmosphere to a height of 3 to 5 m. The dispersion of fog over an area of several tens of km² would require several such units.

Aerosol Generators [pp. 358-361]

The formation of ice nuclei from silver iodide and similar substances is accomplished with the use of special generators, most of them based on the Vonnegut generator. Such an aerosol generator was built at the Central Aerological Observatory. The aerosols are formed during the combustion of the silver iodide solution in acetone in a hydrogen flame. The basic parts in this generator are 1) a gas burner, 2) a cylinder with a hand compressor for storing the solution, 3) a hydrogen cylinder with a reducer, 4) a panel for fixing the gas burner to the combustion chamber, and 5) a ski to which the assembly is attached.

Silver iodide dissolves poorly in acetone but quite well in acetone solutions of such iodides as KJ, NaJ, NH₄J, etc. A solution of NaJ or KJ in acetone is first prepared and the required amount of AgJ is dissolved in it. Usually solutions are used in which 200 g of AgJ are dissolved in a liter of acetone. The dosage of silver iodide is determined by the problem at hand. For example, in dispersing fog, the optimum amount is 1 to 2 g/min. In activating thick cumulus clouds, this amount should be increased.

Some generators which are similar to furnaces have a blower for burning charcoal soaked in a solution of silver iodide. For seeding from a plane, P. N. Krasikov suggested preparing special briquets consisting of charcoal, AgJ, and mazut.

In generating silver iodide smoke aerosol, particles of different sizes are formed. Only particles which reach certain critical sizes may serve as crystallization centers. The critical size of particles increases with temperature. In burning 1 gram of silver iodide at a temperature of -10°C in the generator described, about 10¹⁸ active particles are formed, their number increasing to 10¹⁸ when the temperature falls to -20°C.

The size of silver iodide smoke particles formed in this type of generator is between $3.5 \cdot 10^{-5}$ and $7 \cdot 10^{-7}$ cm. These sizes are close to the size obtained by P. N. Krasikov and N. V. Mamontov, who showed that the majority of particles formed by different methods of distilling iodide compounds of silver and lead are between $1 \cdot 10^{-6}$ to $8 \cdot 10^{-6}$ cm. A large number of smaller particles are also formed at this time. However, even at low temperatures the small

particles cannot be active crystallization nuclei under ordinary saturation conditions over water and ice.

The Central Aerological Observatory found that, with an increase in the outlay of silver iodide, the number of particles formed from 1 gram decreases; this is probably due to the increased size of the particles generated.

Use of Rockets in Dispersing Clouds [pp. 361-362]

Rockets are cheaper and simpler to use than airplanes for dispersing clouds. A rocket may be used to activate either a particular cloud or a field of clouds over a large territory. [Translator's note: The data provided are for an Italian rocket. No details are furnished on Soviet rockets.]

Modification of Clouds Results of Experiments in Activating Clouds and Fogs [pp. 362-374]

The relationship between the amount of solid carbon dioxide (CO_2) or silver iodide used and the amount of precipitation induced in seeding cumulus clouds has not yet been thoroughly investigated. Overseeding of clouds of relatively small vertical thickness should be avoided because the number of ice nuclei formed grows to such an extent that they prevent the formation of large particles.

The effectiveness of dispersed water is much lower than that of solid carbon dioxide or silver iodide, which points out the importance of the solid phase in the formation of precipitates.

In the USSR, the study of methods of countering the formation of hail in large cumulus clouds has been conducted mainly in the Alazanskaya Valley in the Gruzinskaya [Georgian] SSR by the Academies of Sciences of the USSR and the Gruzinskaya SSR, the Hydrometeorological Service, the Central Aerological Observatory, the Main Geophysical Observatory, and the Tbilisi Scientific Research Hydrometeorological Institute. In activating clouds, special rockets are used to deliver dry ice or silver iodide into the supercooled part of the cloud. Hygroscopic reagents and dry ice are introduced into the clouds additionally from a jet plane.

In dispersing supercooled clouds and fog over airports, solid carbon dioxide is introduced into the cloud with the use of an airborne automatic metering device. This method, however, can be used for clearing airports only under certain meteorological conditions. The seeding takes place some distance from the airfield so that the cleared space travels to the airport. This requires that the velocity and direction of the wind at the upper level of the clouds be determined in advance.

In dispersing supercooled fogs, ground CO₂ equipment may be used. Particles of CO₂ released by the unit bring about a phase transformation in the fog. The latent heat released in the process of crystallization increases turbulence, which carries the crystal nuclei into higher layers. The resulting cleared area is about the same size as that produced with an airplane. The location of the units around the airfield depends on the direction of the wind.

Experiments conducted by the Central Aerological Observatory showed that supercooled clouds may also be dispersed with the use of silver iodide and an aerosol generator. Two and one-half to five square kilometers may be cleared with one generator. In most of the experiments, 10 to 15 min of spraying resulted in 40 to 45 min of maintained clearance, which is sufficient for takeoff or landing.

Microstructural observations indicate that crystals in a fog begin to appear 1 to 3 min after spraying. The crystals are usually hexagonal. Samples taken 30 to 40 min after spraying showed fairly small crystals 15 μ in size. This shows that particles of silver iodide do not develop all their ice-forming properties simultaneously and that their action probably is determined by their size.

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- SOURCES:**
1. Gerasimov, I. P. Soviet geographic science and problems of the transformation of nature. IN: Akademiya nauk SSSR. Izvestiya. Seriya geograficheskaya, no. 5, 1961, 6-16.
 2. Conference on the problems of modification of climate. IN: Akademiya nauk SSSR. Izvestiya. Seriya geograficheskaya, no. 5, 1961, 128-133.

A conference on the problems of modification of climate was held in Leningrad during the period 25 to 28 April 1961 under the sponsorship of the Main Geophysical Observatory and the Institutes of Applied Geophysics and Geography of the Academy of Sciences USSR.

Academician Ye. K. Fedorov, in a paper titled "The Future of Research on the Problem of Modification of Climate," noted that knowledge in this field is still extremely limited and it is impossible to predict the final results of interference in particular climate-forming processes. He believes some 5 to 10 years of work will be required to adequately define the problem and to suggest possible ways in which the climate can be altered. He feels that the best way to bring about such changes is by altering the underlying surface. One way would be to erect major hydraulic structures which would alter the currents in the sea; another way is to remove the ice and snow from the earth's surface or change its albedo. The removal of the ice cover from the Arctic would be permanent; once destroyed it could never be reestablished. There are indications that precipitation can be stimulated by the erection of artificial barriers no higher than 20 to 30 m. The dispersing of clouds over a great area can lead to temperature changes of the order of 10°C, or even changes in pressure.

Academician I. P. Gerasimov gave a report on "Changes in Climate in the Quaternary," one of a number of reports emphasizing that future climate modification can scarcely be brought about without comprehension of such events in the past. He states that an examination of the direct causes for the glacial periods indicates that there were no changes in the composition of the atmosphere and no justification for postulating volcanic activity as causes for the glacial periods. And there were not less than 20 significant variations in insolation during a 1 million year period, which greatly exceeds the number of glacial cycles. It is not only total insolation that counts but also variations in ultraviolet and

corpuscular radiation. The need for further study in heliophysics and paleogeography is obvious.

L. A. Vitel's has predicted climatic changes for the last three decades of the 20th century and the beginning of the 21st century. He anticipates a period of especially low solar activity during this period, accompanied by a weakening of circulation of the atmosphere, a southward displacement of cyclone tracks, an increase in the continentality of the European part of the USSR and western Siberia, and an increase in the natural runoff of the Volga.

The paper presented by M. I. Budyko, "The Heat Balance of the Earth and the Problem of Modification of Climate," gave numerous computations of the heat balance, both as of today and in coming decades. The amount of energy produced by man in 1952 was 30 times less than that produced by photosynthesis and 3000 times less than that of the radiation balance. Vast increases in population and the production of energy by man can result in raising the temperature of the atmosphere by several tens of degrees, to the point where all humanity would perish. He also reported on the changes that would be brought about by destruction of the ice covering the Arctic seas. (He believes that if the ice is destroyed it could never be reestablished under present-day conditions). At the present time, the temperature of the water surface should be $+10^{\circ}\text{C}$ in summer and $+5^{\circ}\text{C}$ in winter. Accordingly, the air temperatures should be $+10^{\circ}\text{C}$ in summer (now below 0°) and $+1^{\circ}\text{C}$ in winter (now -33°). He has even computed that the melting of this ice by artificial methods would require an expenditure of energy equal to that now produced by human society in 30 years.